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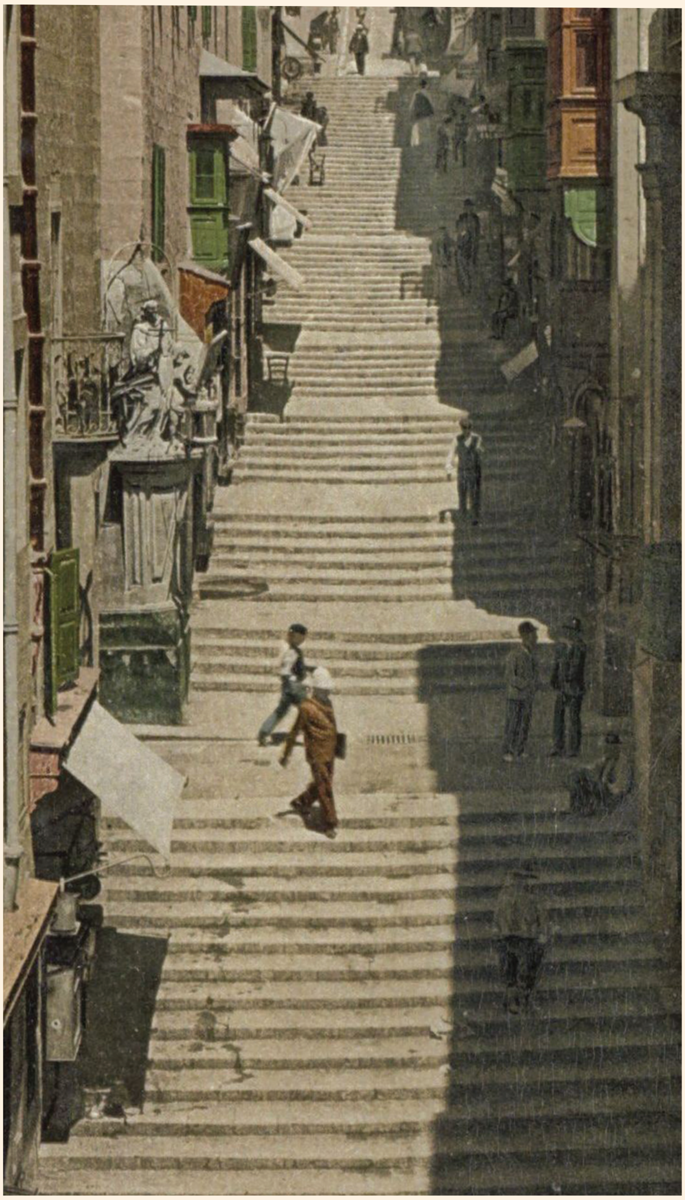
The Long Term *Growth* Model



Edited by
Norman V. Loayza
Steven Pennings

Fundamentals, Extensions, and Applications

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Acknowledgments

Many people have made important contributions to make the LTGM project—and this book—possible.

First, we are indebted to a small group of people who helped get the LTGM project off the ground. Constantino Hevia was key in this area; in collaboration with Norman Loayza, he co-wrote the first version of the proto-LTGM in a policy application to Egypt around a decade ago (which is now chapter 9 in this volume). We thank Constantino for his insights in formulating the model, many of which still permeate LTGM today. Two other people helped turn the original application, written in Matlab code for a single country, into an accessible spreadsheet-based tool for all countries. The first is Vinaya Swaroop, who as the World Bank's Global Lead for Growth in the early days of the LTGM project realized the LTGM's potential and helped fund its development and encourage its use. The second is Leonardo Garrido, who was Steven Pennings's main collaborator at the time the first LTGM toolkit was formed (and had produced his own variant of Hevia and Loayza's model). Many of the ideas that make the LTGM spreadsheet accessible and easy to use were Leonardo's, and he did much of the hard work in forming the first version of the LTGM spreadsheet with preloaded data for all countries. Diego Barrot also helped with much of the early data analyses.

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From the standpoint of fighting world poverty, nothing is more important than figuring out which policies differentiate the fast-growing countries from the slow-growing ones.

Robert Barro (2002)

Introduction[1]

Norman V. Loayza and Steven Pennings

Motivation

Economic growth is the foundation on which social and economic development rests.[2] Although it may not be a sufficient condition for prosperity, it certainly is a necessary condition. Economic growth is needed to create jobs and generate income opportunities, particularly in countries where young people are joining the labor market in increasing numbers.[3] Economic growth can foster innovation and entrepreneurship, which in turn increases future growth, generating a virtuous cycle.[4] It can be the foundation of political and social stability, especially if it is inclusive and sustained.[5] Economic growth provides resources for well-managed governments to build infrastructure, from ports and roads to internet connection hardware and public services, from contract enforcement to public safety.[6]

Economic growth is, therefore, the key to poverty alleviation, an essential objective of most, if not all, developing country governments and international development organizations, such as the World Bank.[7] Moreover, economic growth can contribute to reduced inequality and widespread prosperity if conditions of governance, inclusivity, and sustainability are met.[8]

It is not surprising, therefore, that most policy makers around the world care deeply about economic growth. In fact, virtually all *national development plans* feature economic growth projections for their countries.[9] These growth projections are often aspirational: they present what the country *needs* to develop and prosper and, therefore, tend to be overly ambitious.

Though it is understandable why governments may want to "shoot for the moon" with their growth forecasts, formulating unrealistic projections is misguided. They may lead to unsustainable levels of public deficit and debt, as governments may assume that they can grow their way out of debt.[10] More generally, unrealistic expectations distort the planning of public and private services and investment. They create false expectations among the public, which can lead to frustration and social instability. In the long run, unrealistic growth projections hamper the credibility of those who formulate them and confuse and disappoint those who use them.

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[1] We are grateful to Federico Fiuratti for excellent research assistance.

[2] Lucas 1988; Barro and Sala-i-Martin 2004; Acemoglu 2007; Jones and Vollrath 2013; Commission on Growth and Development 2008.

[3] Cerra et al. 2022.

[4] Romer 1990; Aghion and Howitt 1992; Kremer 1993; Jones 1995; Barro and Sala-i-Martin 1997; Aghion, Akcigit, and Howitt 2015; Akcigit, Celik, and Greenwood 2016; Akcigit and Kerr 2018; Acemoglu, et al. 2018.

[5] Alesina and Rodrik 1994; Barro 1991.

[6] Easterly and Rebelo 1993.

[7] Banerjee and Duflo 2020; Dollar and Kraay 2002; Kraay 2006.

[8] Acemoglu, Johnson, and Robinson 2005; Sala-i-Martin 2006; Easterly 2006; Cerra, Lama, and Loayza 2022.

[9] Chimhowu, Hulme, and Munro (2019) report that the number of countries with a national development plan has risen from about 60 to over 130 in the last two decades. Analyzing over 100 national development plans, they identify the types and content of the plans, their implications for sustainable development agendas, and the ownership and political control of the processes leading to the formulation of the national development plan.

[10] Easterly 2001.

Origins

The *Long Term Growth Model* (LTGM) was initially created as a basic, yet sound, way of assessing whether growth projections were realistic or not. It used a standard neoclassical growth model, with exogenous saving/investment and productivity rates, to formulate growth paths based on observable initial conditions and reasonable assumptions on future growth drivers. However, it was soon clear that the LTGM could do more than serve as a "reality check"; it had the potential to describe alternative growth scenarios and the determinants behind those scenarios. This proved to be very useful to development practitioners, not only to generate more feasible growth paths but also to understand the potential impact of different growth drivers that could be affected by economic policy. The model also helped advise policy makers how growth might evolve in a business-as-usual scenario where those growth drivers were unchanged.

This interest in the LTGM also generated a strong demand to make it richer and more complex, as users posed questions that the standard LTGM could only partially address. The LTGM project expanded in response to this demand and is now a suite of diverse and powerful models. These improvements, implemented in specific papers and toolkits, consisted of examining the determinants of total factor productivity with particular emphasis on policy, differentiating between public and private capital in their rates of return and efficiency, accounting for natural resources as a complementary source of growth, and measuring the impact not only on economic growth but also on poverty alleviation. Along with these technical refinements, the LTGM as a project grew also in its applications to a diverse set of countries.

This book

This book is a collection of the technical papers that serve as background for the LTGM suite of models and a selection of some of its country-specific applications. One of the main advantages of not only the standard LTGM but also all its extensions is that they can be implemented using user-friendly spreadsheet-based toolkits. They, along with basic data to run the models and information on some of their applications, can be found on the LTGM website: https://www.worldbank.org/LTGM. The list of the contributors who have made this project possible, and to whom we are immensely grateful, are recognized in the *Acknowledgments* of this book.

As implied in its title, the book is divided into three sections: fundamentals, extensions, and applications. The fundamentals of the LTGM are presented in chapter 1. The model extensions to the standard LTGM are presented in chapters 2–4. And the country-specific applications, covering different angles and contexts, are presented in chapters 5–10.

Fundamentals

Chapter 1, "The Standard Long Term Growth Model," presents the simplest version of the LTGM, which adapts the Solow (1956)-Swan (1956) model for analyzing future growth paths in developing countries. The standard LTGM is designed to be sufficiently simple so that it can be solved in a spreadsheet—to make the simulations fully transparent—and to have sufficiently low data requirements so that it can be used in almost any country. Unlike many growth models, the LTGM focuses on future transition paths (rather than steady states) as convergence to a new steady state is sufficiently slow so that the transition period is more relevant for policy makers. The LTGM toolkit also includes a poverty module to calculate the effect of simulated future growth paths on poverty reduction.

Like the original Solow-Swan model, the LTGM features exogenous saving/investment rates, total factor productivity (TFP) growth, and population growth. However, the LTGM brings some refinements by allowing for richer demographics (such as population aging or a "demographic dividend"), labor force participation rates by gender, human capital (years of schooling), and types of foreign savings (the current account deficit or external debt and foreign direct investment). The model allows users to simulate economic growth rates based on initial conditions and assumptions of the future behavior of its drivers; alternatively, the model allows users to determine the investment (and corresponding saving) needs given a target long-run growth rate. Users can also experiment with different ways to accelerate growth.

Extensions

Chapter 2, "Assessing the Effect of Public Capital on Growth," separates the capital stock into public and private portions in order to analyze the effect of an increase in the quantity or quality of public investment on growth. The chapter constructs a new Infrastructure Efficiency Index (IEI) by combining quality indicators for power, roads, and water. In the model, public investment generates a larger boost to growth if existing stocks of public capital are low (relative to gross domestic product [GDP]) or if public capital has a larger role in the production function. The chapter draws four implications. First, since the measured public capital stock is roughly constant as a share of GDP across income groups, the growth effect of new public investment is roughly constant across development levels. Second, since developing countries are relatively short of private capital, private investment provides the largest boost to growth in those countries. Third, although improving the efficiency of public investment has a sizable effect on growth in low-income countries, the level of efficiency, if constant, does not affect the return to public investment. And fourth, an expansion of public investment generates a modest but diminishing boost to growth in most developing countries.

Chapter 3, "Productivity Growth: Patterns and Determinants across the World," attempts to link TFP to economic and institutional reforms, thus making TFP less exogenous. The chapter identifies the main determinants of TFP as innovation, education, market efficiency, infrastructure, and institutions. It then constructs indexes representing each of these categories and, combining them through a principal component analysis, obtains an overall determinant index for more than 100 countries annually for 1985–2015. The chapter then examines the relationship between these determinant indexes and existing measures of TFP through a variance decomposition and regression analysis. The variance decomposition shows that the largest share of the variance in TFP growth is explained by market efficiency for advanced countries and education for developing countries. The regression analysis shows that, controlling for country- and time-specific effects, TFP growth has a positive and significant relationship with the overall determinant index and a negative relationship with initial TFP. Chapter 3 uses this relationship to formulate a set of simulations on the potential path of TFP growth for various improvements in TFP determinants. The chapter presents and discusses some of these simulations for groups of countries by geographic region and income level. This serves to illustrate how this extension can be used to generate a path for TFP that can be fed into the standard LTGM spreadsheet.

Chapter 4, "Assessing the Effects of Natural Resources on Long Term Growth," analyzes how long-run growth evolves in resource-rich countries. In particular, it evaluates how commodity price shocks and discoveries/depletion of natural resources affect a country's economic growth, and how this depends on different fiscal policy frameworks. For this purpose, the chapter adds a natural resource sector and government fiscal policy to the standard LTGM. Commodity price shocks affect long-term economic growth mostly by raising revenues for public investment. As a large share of resource income typically accrues to the government, the increase in investment during a commodity price boom depends on the government's fiscal rule. Fiscal rules that prioritize public investment generally lead to the largest increases in long-term growth.

However, structural surplus rules, which save commodity revenues, can also boost growth if they free up savings for private investment. The response of incomes to natural resource discoveries is similar to the response to price shocks; however, discoveries produce a direct effect on real GDP in addition to the indirect effect through investment. This two-sector model also allows for a more accurate analysis of the effect of other (non-resource) fundamentals on growth than the standard LTGM in resource-rich countries by accounting for heterogeneity across sectors and the consequences of depleting reserves of natural resources. However, since this is a supply-side model, it does not capture the short-run effects of price and discovery shocks that operate through aggregate demand.

Applications

Chapters 5–10 present applications of the standard LTGM and its extensions to different countries around the world. In addition, chapters 2–4, while focusing on LTGM extensions, also include country applications to illustrate their models. For instance, chapter 3, on the drivers of total factor productivity, considers various reform scenarios in Peru and corresponding TFP and economic growth projections; likewise, chapter 4, on the natural resource extension, calibrates the model to Angola, a major oil producer, and presents several simulations based on different scenarios of fiscal policy.

Chapters 5 and 6 study future and past growth in two rapidly developing Asian economies. Chapter 5 studies economic growth in Malaysia, with some historical analysis, but mostly with the purpose of assessing Malaysia's potential to sustain growth as it transitions to high-income status. It assesses the challenges Malaysia faces in this regard, particularly the need to increase female labor force participation and improve the educational performance of its young population. Chapter 6 studies the Republic of Korea's growth process—not looking forward—but as a retrospective of the remarkable growth experience of the country in the last six decades. It notes how the main engine of growth in the Republic of Korea has evolved from labor and human capital in the 1960s, to physical capital deepening in the 1970s, and to productivity growth in the subsequent decades.

Chapters 7 and 8 consider two economies in South Asia and the Middle East with different growth trajectories. Chapter 7 applies the LTGM to Bangladesh, recognizing the country's robust economic growth in the last several years and assessing whether it will be able to maintain high growth rates in the future. The chapter concludes that capital investment, even at reasonably high rates, will not be able to sustain strong growth if investment is not accompanied by productivity enhancing reforms. Chapter 8 studies the very different case of Syria, a country devasted by a brutal war, and considers potential growth scenarios in the aftermath of war. Syria's growth will be driven by reconstruction assistance, repatriation of refugees, and productivity improvements, and in turn determined by the post-war political settlement the country is able to achieve.

Finally, the last two chapters of this volume present early applications of the predecessor of the LTGM. Chapter 9 presents the first application of a proto-LTGM, where its analytical underpinnings are developed. It studies the possibilities and limits of a saving-based growth agenda in Egypt. It concludes that if the Egyptian economy does not experience productivity growth, stemming from technological innovation, improved public management, and private-sector reforms, then a high rate of economic growth would require saving rates that are highly unrealistic. Chapter 10 is chronologically the second application of the proto-LTGM model. It documents the robust growth performance in Sri Lanka fueled by a large increase in private savings in previous decades and asks whether these trends can be maintained. The chapter considers the determinants of private saving rates and finds that they are likely to decline because of the looming demographic transition in Sri Lanka. The chapter concludes that growth rates could remain high only if public savings rise and the business environment improves, attracting foreign investment and increasing productivity.

Lessons

The LTGM project has produced a multitude of findings and policy implications in a wide array of country-specific applications conducted over the past decade. Though it is hard to summarize these findings and implications, the following four takeaways are worth highlighting.

1. Although all fundamental economic conditions contribute to growth, their relative importance varies across countries. This means that growth performance, constraints, and opportunities also vary with country context. Country-specific conditions determine how sustainable growth is, what growth rates are feasible, and which paths are the most effective to accelerate growth; and these often vary substantially across countries. Having said that, the main growth drivers—TFP, human capital, physical capital, and labor—are all qualitatively important, and analyzing growth in these terms provides a framework that is relevant in a wide variety of country contexts.

2. *Investment-led growth strategies are unsustainable in the long run.* Physical capital investment, fueled by domestic and external saving rates, can jump-start growth and keep it going for some years. This, however, cannot be the basis of a long-run development strategy. Growth rates will fall as the capital stock expands and the inevitable diminishing marginal productivity of capital sets in. To be sustainable, growth must be broad-based, including progress in human capital, productivity, and/or labor force participation. This applies not only to total investment but also to public investment.

3. *It is hard to have high investment rates without high national savings rates.* If capital accumulation is relied upon to increase growth in the short and medium terms, the sources of funding cannot be external for extended periods of time. External financial constraints will bite sooner rather than later, exposing the country to a sudden stop or even reversal of capital flows and producing a collapse in growth rates.

4. *High growth usually involves fast productivity growth.* The key to sustainable economic growth in the long run is "total factor productivity" growth: the ability of firms to innovate and adopt new technologies and achieve an efficient allocation of resources among firms and sectors in the economy. This is more likely with a well-educated population, good infrastructure, effective government institutions, and a business-friendly environment that rewards efficiency.

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Chapter 1

The Standard Long Term Growth Model[1]

Norman V. Loayza and Steven Pennings[2]

Abstract

The standard Long Term Growth Model (LTGM) is a spreadsheet-based tool to analyze future long-term growth scenarios in developing countries, building on the celebrated Solow-Swan growth model. The focus of the tool is on simplicity, transparency, and ease-of-use, and it can also be used to assess the implications of growth for poverty rates. The very low data requirements mean the tool can be applied in almost any country, and most of the required data are preloaded. Total factor productivity (TFP), investment/savings, and human capital are key growth drivers, but the model includes other growth fundamentals, such as demographics and labor market participation (disaggregated by gender). While growth constraints and opportunities are heterogeneous across countries, the most common result when applying the LTGM in developing countries is that investment-led growth is unsustainable in the long run. This is due to a rising capital-to-output ratio when investment is driving growth, which implies a diminishing marginal product of capital (MPK) that reduces the effectiveness of new investment. Instead, sustainable growth requires broad-based growth fundamentals, such as fast TFP or human capital growth, to keep the capital-to-output ratio down. Another challenge of high investment rates is that they usually require high rates of domestic savings.

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[1] **Editors' note:** This chapter is an expanded version of the model description of the standard LTGM on the LTGM website: https://www.worldbank.org/LTGM. As such is it a little more technical than other chapters, and equation numbers correspond to those in the LTGM spreadsheet. It builds on the model in Hevia and Loayza (2012), which is chapter 9 of this volume.

[2] Both World Bank. Authors' emails: nloayza@worldbank.org and spennings@worldbank.org. The views expressed here are the authors', and do not necessarily reflect those of the World Bank, its Executive Directors, or the countries they represent. The authors are grateful to Aart Kraay, Luis Serven, and Arthur Mendes for helpful comments and Jorge Luis Guzman and Federico Fiuratti for research assistance. The authors also thank the Global Facility for Growth for Development Trust Fund, supported by the Korean government, for financial support.

Introduction

The standard Long Term Growth Model (LTGM) is a spreadsheet-based tool to analyze future long-term growth scenarios in developing countries. The tool helps policy makers answer important questions in their own country, including: What growth goals are feasible? What combination of growth drivers (investment, human capital, productivity, etc.) are required to achieve these growth goals? What growth rates might occur if current trends in growth drivers continue? How sustainable is growth? What are the effects on poverty? These questions lie at the heart of most growth strategies and help to link broad development goals with specific policy interventions (promoting investment, increasing competition, etc). The standard LTGM seeks to answer these questions in a simple and transparent way, and with sufficiently low data requirements that the model can be applied in almost any country. Chapters 5–10 of this volume provide a series of country case studies of how to apply the LTGM in practice.

The LTGM builds on the celebrated neoclassical Solow (1956)-Swan (1956) growth model, but extends the model in several ways, and adapts it to the needs of policy makers.[3] Investment/savings, TFP, and population growth are key growth drivers as in the classic Solow-Swan model. However, the LTGM setup also includes other growth drivers that are important in developing countries such as human capital, population aging, and labor market participation (especially for women). Moreover, as most developing countries have at least partially open capital accounts, the LTGM allows for a more detailed analysis of external savings, including foreign direct investment and external debt. Based on the needs of policy makers, the LTGM focuses on transition paths (rather than steady states) and includes a poverty module. Transition paths are more useful for policy makers as convergence to a new steady state is often slow.[4] The inbuild poverty module captures the effect of growth (and inequality) on poverty, based on a log-normal approximation of the income distribution.

The standard LTGM connects "Solow growth fundamentals" and economic growth in developing countries, rather than connecting specific policies (or their ultimate determinants) to growth. Policy makers are often interested in connecting individual policies with growth outcomes, but this task is difficult.[5] The conceptual approach of the LTGM breaks down this causal chain from policies to growth into two pieces: first from policies to "Solow growth fundamentals" like investment, TFP, human capital, and population growth, and second from these "Solow growth fundamentals" to economic growth. The LTGM analyzes the second macroeconomic part of the chain, which can be thought of as reverse growth accounting in the future.[6] As in a regular growth accounting exercise, the LTGM can be used to understand the *proximate* sources of growth in a baseline under current trends, and compare the growth impact of changes in different growth fundamentals as policy makers try to accelerate growth. However, the first part of the chain, from policies to Solow fundamentals, can be sourced from elsewhere, including microeconomic studies or country-specific judgement.[7]

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[3] The current version of the LTGM builds on earlier work by Hevia and Loayza (2012), which is chapter 9 in this volume.

[4] Moreover, developing countries are often buffeted by large and persistent shocks (shifting the steady state), and most developing countries do not have the stable long-run growth rates of the US that motivated a focus on steady states.

[5] See for example, Easterly (2001). Part of the problem is a lack of exogenous variation in policies.

[6] In a standard growth accounting exercise, one starts with a historical growth series and decomposes it into paths for different growth fundamentals.

[7] For example, the education literature has many estimates of the effect of different policy interventions on schooling rates. The LTGM does not recommend specific policies itself as this also depends on the first stage of the chain: policies that boost investment in country A might not work in country B.

The LTGM is useful for long-run analysis, including planning/vision documents, but shouldn't be used for short-run growth analysis or forecasting. While the LTGM does produce year-to-year movements in growth, in the short term these should be interpreted as the growth rate of *potential* gross domestic product (GDP), not actual GDP. This is because the LTGM doesn't include demand-side relationships that are important in the short term.[8] The LTGM also doesn't provide a *forecast* of long run growth (what growth rates *will* occur). This is partially because policies or growth fundamentals themselves might change, but also because the long run is too uncertain for forecasts to be useful. Instead, LTGM simulations can be thought of as a *conditional* long-run forecast; if Solow fundamentals evolve in a particular way, then growth will follow a particular path. This is useful because one can utilize the cross-country distribution of growth fundamentals to determine the feasibility of growth plans. For example, if growth targets can only be achieved with investment rates (or other growth fundamentals) that don't typically occur in other similar countries, policy makers might like to rethink the feasibility of those targets.[9]

In practical terms, using the LTGM involves calibrating several parameters and then making assumptions about the evolution of future growth fundamentals (or targets) until the end of the simulation period (usually 2050). The few parameters required can usually be calibrated from international data sets such as the Penn World Tables (PWT) or World Bank Development Indicators (WDI). Demographers at the United Nations produce projections of population growth and other demographic variables. Future values of other variables require more judgement, but can be based on the continuation of recent country-specific trends or the performance of peer countries. For example, in some countries the investment share of GDP might oscillate around a stable long-term average, and so that average would be a good assumption for the future investment rate. Conversely, if TFP growth was volatile but had been exceptionally high in recent years due to one-off factors, a better assumption might be for it to revert to a regional or income group mean over time.[10] Finally, users should take account of the natural bounds on different variables: human capital (schooling rates) and labor force participation rates are bounded above, and so the growth rates of each are likely to slow as a country approaches the frontier for these variables.

While analyses conducted using the standard LTGM usually find growth constraints and opportunities are heterogeneous, a few common results are apparent in different country contexts. The most common of these is that popular investment-led growth strategies are unsustainable in the long run. This is due to a rising capital-to-output ratio when investment is driving growth, which implies a diminishing MPK that reduces the effectiveness of new investment for growth. Instead, sustainable growth requires broad-based Solow fundamentals, such as fast TFP growth or fast human capital growth, to keep the capital-to-output ratio down. Moreover, high rates of investment need to be financed by either domestic or foreign savings. As foreign savings can be fickle, high rates of investment in the long run usually require high rates of domestic savings. Both of these common results are well known in the literature, and so the LTGM's contribution is in quantifying their size in specific countries, and also making them more accessible to policy makers.[11]

The rest of this chapter proceeds as follows. Section 1 provides an overview of the standard LTGM in terms of its three building blocks—a production function, demographics/labor market, and capital

[8] The World Bank MFMod is designed to capture these relationships; see Burns et al. (2019).

[9] In sub-model 2 of the LTGM, one can enter a target GDP growth rate and calculate the required investment share of GDP to achieve that target (conditional on other growth fundamentals).

[10] Regional or income group trends can also be used to interpolate missing data.

[11] More specifically, the inability of investment to generate long-run growth is built into any neoclassical growth model with diminishing returns to capital, including the original Solow (1956) and Swan (1956) papers. It has been verified empirically in development accounting exercises where capital deepening does not play a large role in explaining cross-country income variation; see Hall and Jones (1999). The strong relationship between domestic savings and investment in open economies was famously documented in Feldstein and Horioka (1980).

accumulation—and describes how to calibrate parameters and universal growth drivers (as in InputDataA of the LTGM spreadsheet). Section 2 outlines the three sub-models in the LTGM spreadsheet (as in InputDataB): sub-model 1 where a given investment path (input) affects growth (output); sub-model 2 which is used to calculate the investment rates (output) required to achieve a given growth target (input); and sub-model 3 where paths for savings (domestic and foreign) are used as an input rather than a path for investment. Section 3 derives an analytical equation for growth drivers, and provides some intuition for common results. Section 4 presents the poverty module of the LTGM based on a log-normal approximation of the income distribution. Section 5 concludes with some caveats and links to future extensions. Equation numbers in this chapter correspond to those in the standard LTGM spreadsheet.

1. An overview of the Long Term Growth Model

In this section we outline the main equations of the LTGM, which apply in all three sub-models. We also discuss how to calibrate parameters and universal growth drivers (these are entered in *InputdataA* in the LTGM spreadsheet).

The production function. The first building block of the standard LTGM is a Cobb-Douglas production function as in equation 1, where Y_t is GDP, A_t is the total factor productivity, K_t is the physical capital stock, and h_tL_t is *effective* labor used in production, which can be further decomposed as h_t human capital *per worker* (based on the years of schooling), and L_t as the number of workers. β is the labor share (the share of GDP that accrues to workers).

$$Y_t = A_t K_t^{1-\beta} (h_t L_t)^{\beta} \tag{1}$$

One can divide both sides by L_t to get variables in per worker terms (denoted as lowercase letters without a superscript), where k_t is capital per worker and h_t is already in per worker terms:

$$y_t \equiv \frac{Y_t}{L_t} = A_t k_t^{1-\beta} h_t^{\beta}$$

From this equation we can calculate gross growth rates of output per worker from t to t+1:

$$\frac{y_{t+1}}{y_t} = \frac{A_{t+1}}{A_t} \left[\frac{k_{t+1}}{k_t}\right]^{1-\beta} \left[\frac{h_{t+1}}{h_t}\right]^{\beta}$$

Rewrite this equation in terms of $g_{y,t+1}$, the growth rate of GDP *per worker* from t to t+1 (e.g., 0.05). In equation 2, output per worker growth is driven by productivity growth ($g_{A,t+1}$, the growth rate of TFP), capital accumulation ($g_{k,t+1}$, the growth rate of capital per worker), and human capital growth ($g_{h,t+1}$, the growth rate of human capital per worker).

$$1 + g_{y,t+1} = (1 + g_{A,t+1})[1 + g_{k,t+1}]^{1-\beta}[1 + g_{h,t+1}]^{\beta} \tag{2}$$

Demographics and labor market variables. The second building block is demographics and labor market variables, which allow per worker variables to deviate from per capita variables (the latter are denoted in lowercase with a "PC" superscript, i.e., y_t is output per worker and y_t^{pc} is output per capita). N_t is the total population, and so the number of workers can be decomposed into $L_t = \varrho_t \omega_t N_t$ where ϱ_t is the labor force participation rate (labor force/working-age population) and ω_t is the working-age population to total population ratio.[12] Divide equation 1 by N_t to get all variables in per capita terms.

[12] The LTGM assumes no unemployment or underemployment, so everyone in the labor force is employed. This is because the concept of active job search, which distinguishes unemployment from nonparticipation in the labor market, is poorly defined in many developing countries with high rates of informality or missing labor market institutions for job searches.

$$y_t^{pc} \equiv \frac{Y_t}{N_t} = \frac{Y_t}{L_t} \varrho_t \omega_t = y_t \varrho_t \omega_t = A_t \varrho_t \omega_t k_t^{1-\beta} h_t^{\beta}$$

$$\frac{y_{t+1}^{pc}}{y_t^{pc}} = \left[\frac{\varrho_{t+1}}{\varrho_t}\right]\left[\frac{\omega_{t+1}}{\omega_t}\right]\left[\frac{y_{t+1}}{y_t}\right]$$

Growth in output *per capita* is just output *per worker* adjusted for changes in participation and the working-age population. Specifically, for a given growth rate of output per worker, output growth can be driven by a *demographic transition* (growth in the working-age to population ratio $g_{\omega,t+1}$), or an *increase in labor force participation* (growth in the participation rate $g_{\varrho,t+1}$).

$$1 + g_{y,t+1}^{pc} = [1 + g_{\omega,t+1}][1 + g_{\varrho,t+1}][1 + g_{y,t+1}] \tag{3}$$

Physical capital accumulation. The final building block of the LTGM is a capital accumulation identity as in equation 4. That is, physical capital for use in production next period K_{t+1} is equal to new investment today I_t, as well as the undepreciated current physical capital stock $(1 - \delta)\, K_t$ (where δ is the depreciation rate).

$$K_{t+1} = (1 - \delta)\, K_t + I_t \tag{4}$$

In practical terms, this equation is usually expressed in terms of updating the capital-to-output ratio K_t/Y_t:

$$\frac{K_{t+1}}{Y_{t+1}}\left[\frac{Y_{t+1}}{Y_t}\right] = (1-\delta)\frac{K_t}{Y_t} + \frac{I_t}{Y_t}$$

Calibrating the model. One of the advantages of the LTGM is that it only requires three parameters/initial conditions: β (the labor share), δ (the capital depreciation rate), and $\frac{K_0}{Y_0}$ (the initial capital-to-output ratio). Note, however, the calibration of each one can be important for the results. To solve each of the three sub-models, we also need to input paths for exogenous variables which are universal $\{g_{A,t+1}, g_{h,t+1}, g_{\omega,t+1}, g_{\varrho,t+1}, g_{N,t+1}\}_{t=0}^{T-1}$. These variables are specified in the tab *InputdataA* in the LTGM spreadsheet, and graphed in the tab *GraphsA*.

Users can choose parameters, initial values, and exogenous future paths from a range of data sources and time periods using the drop-down menus in the LTGM spreadsheet, or simply type in their own values. Missing parameters or initial values are usually interpolated based on income group medians, which triggers a red warning cell. Parameters are:

- β (the labor share) is taken from PWT (a range of vintages) or the Global Trade Analysis Project (GTAP) database. 0.4–0.7 are usually considered reasonable numbers (as a rough guide).
- δ (the capital depreciation rate) and $\frac{K_0}{Y_0}$ (the initial capital-to-output ratio) are taken from PWT (a range of vintages).[13]

Common growth drivers across all three sub-models are:

- $g_{A,t+1}$ (exogenous total factor productivity growth). Reasonable numbers are 0% (pessimistic), 1% (moderate), or 2% (optimistic). Faster productivity growth can be obtained from (for example) technology adoption, greater competition, reduced regulation, or factors of production moving from less efficient to more efficient sectors/firms. Historical averages included in the LTGM spreadsheet are calculated from PWT (various vintages and years) or applying PWT 8.1 methodology with GTAP labor shares as in Barrot (2016).

[13] The K_0/Y_0 ratio is calculated as rkna/rgdpna in PWT 8.1 or 9.0, and rnna/rgdpna in PWT 9.1 or 10 (national accounts prices).

- $g_{\varrho,t+1}$ (growth rate of labor force participation, [LFP]). Historical data from the UN or country authorities can be used as a guide. In practice, the most important determinant of $g_{\varrho,t+1}$ is female LFP.
- $g_{N,t+1}$ (exogenous population growth) and $g_{\omega,t+1}$ (growth in the working-age to total population ratio). These are both taken from the World Bank Health Nutrition and Population Statistics: population estimates and projections (link) with $g_{\omega,t+1}$ determined by the age structure of the population.
- $g_{h,t+1}$ (exogenous human capital per worker growth) is usually taken from PWT (various years). Higher human capital growth is usually due to more schooling of the workforce.[14]

2. The three sub-models in the LTGM spreadsheet

This section provides details on the three standard LTGM sub-models, which switch inputs and outputs to adapt the LTGM to a variety of questions and country contexts. In the LTGM spreadsheet, these are specified in tab *InputdataB*, and the assumptions and outputs are graphed in tab *GraphsB*. Sub-model 1 is where a given investment path (input) affects growth (output); sub-model 2 is used to calculate the investment rate (output) required to achieve a given growth target (input); and sub-model 3 starts with paths for savings (domestic and foreign) as an input rather than a path for investment as in Submodel 1.

2.1 Sub-model 1: Growth given investment

Sub-model 1 is the most commonly used sub-model of the LTGM, and is also the simplest. The user chooses a path for the future investment share of GDP, $\frac{I_t}{Y_t}$, and then the LTGM calculates the growth path implied (which also depends on the universal growth drivers listed above). The user's choice of the investment rate could be based on historical averages taken from the nominal investment share of GDP in the World Bank's World Development Indicators (NE.GDI.FTOT.ZS), from similar historical averages from the MFMod data set, from forecasts by international organizations or using the user's own judgement.

The equations of sub-model 1 are very similar to those at the core of the main LTGM discussed above. The only extra step is to rewrite capital accumulation identities. Start with equation 4 and divide by L_t.

$$\left[\frac{K_{t+1}}{L_{t+1}}\right]\left[\frac{L_{t+1}}{L_t}\right]=(1-\delta)\frac{K_t}{L_t}+\frac{I_t}{L_t}$$

Now write in terms of growth rates and in *per worker* terms.[15]

$$k_{t+1}\{1+g_{\varrho,t+1}\}\{1+g_{\omega,t+1}\}(1+g_{N,t+1})=(1-\delta)k_t+i_t$$

Next divide everything by k_t

$$\frac{k_{t+1}}{k_t}(1+g_{N,t+1})\{1+g_{\varrho,t+1}\}\{1+g_{\omega,t+1}\}=(1-\delta)+\frac{i_t}{k_t}$$

[14] Hevia and Loayza (2012) refer to this as $h_t=e^{\phi(E_t)}$, which is the efficiency of workers with E_t average years of schooling. If $E_t=0$, $h_t=1$, so h_t represents the efficiency of a worker with E_t years of education relative to one with no education. If $h_t=2$, average workers are twice as productive as a worker with no education. $\phi(E)$ governs the return to an extra year of schooling. PWT is piecewise linear, where the marginal return to schooling is 13.4% for the first four years, 10.1% for the following four to eight years, and 6.8% for years of schooling after that, schooling from Barro and Lee's data set v1.3 (Inklaar and Timmer 2013, see equations 15 and 16). A later variant of PWT also uses Cohen-Soto-Leker's data.

[15] Using $L_t=\varrho_t\omega_tN_t$, labor force growth can be expressed in the following terms, where $g_{N,t+1}$ is population growth between t and $t+1$: $\frac{L_{t+1}}{L_t}=\frac{\varrho_{t+1}\omega_{t+1}N_{t+1}}{\varrho_t\omega_tN_t}=\{1+g_{\varrho,t+1}\}\{1+g_{\omega,t+1}\}(1+g_{N,t+1})$

Then divide and multiply by y_t (output per worker).

$$(1+g_{k,t+1})(1+g_{N,t+1})\{1+g_{\varrho,t+1}\}\{1+g_{\omega,t+1}\}=(1-\delta)+\frac{i_t}{y_t}\frac{y_t}{k_t}$$

Rearrange to get the growth rate of capital *per worker.*[16] Equation 5 determines capital accumulation (in per worker terms), where $\frac{I_t}{Y_t}$ is the investment share of GDP and $\frac{K_t}{Y_t}$ is the capital-to-output ratio.

$$(1+g_{k,t+1})=\frac{(1-\delta)+\frac{I_t}{Y_t}/\frac{K_t}{Y_t}}{(1+g_{N,t+1})(1+g_{\varrho,t+1})(1+g_{\omega,t+1})} \qquad (5)$$

To solve the model, we need to update K_t/Y_t. Start with an initial value K_0/Y_0, and then update the capital-to-output ratio in the next period using equation 6 and the values for $g_{k,t+1}$ and $g_{y,t+1}$ we have calculated in equations 5 and 2:

$$\frac{K_{t+1}}{Y_{t+1}}=\frac{k_{t+1}}{k_t}\frac{y_t}{y_{t+1}}\frac{k_t}{y_t}$$

$$\frac{K_{t+1}}{Y_{t+1}}=\frac{(1+g_{k,t+1})}{(1+g_{y,t+1})}\frac{K_t}{Y_t} \qquad (6)$$

In sub-model 1 we can calculate the growth rate of GDP per capita using the following steps.

1. Calculate the growth rate of capital per worker using equation 5 (using exogenous & predetermined variables, including the path for the investment share of GDP).
2. Calculate the growth rate of output *per worker* using equation 2 (using $g_{k,t+1}$ from step 1).
3. Calculate the growth rate of output *per capita* using equation 3 (using $g_{y,t+1}$ from step 2).
4. Update next period's capital-to-output ratio using equation 6 (using $g_{k,t+1}$ and $g_{y,t+1}$ from steps 1 and 2).

2.2 Sub-model 2: Calculating the investment share of GDP to achieve a given rate of GDP per capita growth

It is straightforward to rearrange the equations above to calculate the investment rate necessary to generate a required rate of per capita GDP growth.

First, calculate the growth rate of output *per worker* consistent with the desired rate of growth of output *per capita,* denoted as $\bar{g}^{pc}_{y,t+1}$, using equation 3, which is rearranged here:

$$1+g_{y,t+1}=\frac{1+\bar{g}^{pc}_{y,t+1}}{[1+g_{\omega,t+1}][1+g_{\varrho,t+1}]}$$

Next substitute this into equation 2

$$(1+g_{A,t+1})[1+g_{k,t+1}]^{1-\beta}[1+g_{h,t+1}]^{\beta}=\frac{1+\bar{g}^{pc}_{y,t+1}}{[1+g_{\omega,t+1}][1+g_{\varrho,t+1}]}$$

[16] Note that $\frac{I_t}{Y_t}=\frac{i_t}{y_t}$ and $\frac{K_t}{Y_t}=\frac{k_t}{y_t}$ because the L_t in numerator and denominator cancel.

Next substitute equation 5 into equation 2 to remove the capital growth rate.

$$(1+g_{A,t+1})[1+g_{h,t+1}]^{\beta}\left[\frac{(1-\delta)+\frac{I_t}{Y_t}/\frac{K_t}{Y_t}}{(1+g_{N,t+1})(1+g_{\varrho,t+1})(1+g_{\omega,t+1})}\right]^{1-\beta}=\frac{1+\bar{g}^{pc}_{y,t+1}}{[1+g_{\omega,t+1}][1+g_{\varrho,t+1}]}$$

Then do some algebra to isolate I/Y on the left-hand side to yield equation 7 in the LTGM spreadsheet.

$$\left[(1-\delta)+\frac{I_t}{Y_t}/\frac{K_t}{Y_t}\right]^{1-\beta}=\frac{\left\{1+\bar{g}^{pc}_{y,t+1}\right\}(1+g_{N,t+1})^{1-\beta}(1+g_{\varrho,t+1})^{1-\beta}(1+g_{\omega,t+1})^{1-\beta}}{(1+g_{A,t+1})[1+g_{h,t+1}]^{\beta}[1+g_{\omega,t+1}][1+g_{\varrho,t+1}]}$$

$$\left[(1-\delta)+\frac{I_t}{Y_t}/\frac{K_t}{Y_t}\right]^{1-\beta}=\frac{\left\{1+\bar{g}^{pc}_{y,t+1}\right\}(1+g_{N,t+1})^{1-\beta}}{(1+g_{A,t+1})[1+g_{h,t+1}]^{\beta}[1+g_{\omega,t+1}]^{\beta}[1+g_{\varrho,t+1}]^{\beta}}$$

$$\frac{I_t}{Y_t}/\frac{K_t}{Y_t}=\frac{\left\{1+\bar{g}^{pc}_{y,t+1}\right\}^{\frac{1}{1-\beta}}(1+g_{N,t+1})}{(1+g_{A,t+1})^{\frac{1}{1-\beta}}[1+g_{h,t+1}]^{\frac{\beta}{1-\beta}}[1+g_{\omega,t+1}]^{\frac{\beta}{1-\beta}}[1+g_{\varrho,t+1}]^{\frac{\beta}{1-\beta}}}-(1-\delta)$$

$$\frac{I_t}{Y_t}=\frac{K_t}{Y_t}\left[\frac{\left\{1+\bar{g}^{pc}_{y,t+1}\right\}^{\frac{1}{1-\beta}}(1+g_{N,t+1})}{(1+g_{A,t+1})^{\frac{1}{1-\beta}}[1+g_{h,t+1}]^{\frac{\beta}{1-\beta}}[1+g_{\omega,t+1}]^{\frac{\beta}{1-\beta}}[1+g_{\varrho,t+1}]^{\frac{\beta}{1-\beta}}}-(1-\delta)\right] \quad (7)$$

Given $\{\bar{g}^{pc}_{y,t+1}\}_{t=0}^{T-1}$ one can calculate required investment using equation 7. As before, future values of $\frac{K_t}{Y_t}$ can be updated for period t+1, t+2 using equation 6 with the growth rate of capital calculated from equation 5. Equation 7 states that required investment is increasing in the desired per capita growth rate $\bar{g}^{pc}_{y,t+1}$, the deprecation rate δ, the population growth rate $g_{N,t+1}$, and the capital-to-output ratio K_t/Y_t. Growth in productivity ($g_{A,t+1}$), human capital ($g_{h,t+1}$), the working-age population ratio ($g_{\omega,t+1}$), and the participation rate ($g_{\varrho,t+1}$) all reduce the required investment rate.

2.3 Sub-model 3: The external balance constraint (growth given savings)

The final sub-model of the LTGM starts with an exogenous path for domestic savings as a share of GDP. This savings path is converted into investment using a binding external balance constraint which can either be in the form of a path for (i) the current account balance CAB_t/Y_t or (ii) external debt D_t/Y_t and foreign direct investment FDI_t/Y_t (all three variables expressed as share of GDP).[17] In sub-models 1 and 2, *implied* savings are calculated endogenously to fund investment rates as a memorandum item. In sub-model 3, investment is determined as the sum of domestic savings less the current account balance (equation 8).

[17] Initial values of CAB_t/Y_t are taken from the MFMod Database and WDI. The World Development Indicators are the source of FDI_t/Y_t (code: BX.KLT.DINV.WD.GD.ZS.) and D_t/Y_t (calculated as DT.DOD.DECT.CD ÷ NY.GDP.MKTP.CD).

2.3.1 A current account balance constraint

The model is simplest assuming a path CAB_t/Y_t.[18]

$$\frac{I_t}{Y_t}=\frac{S_t}{Y_t}-\frac{CAB_t}{Y_t} \tag{8}$$

In sub-model 3 (*CAB/Y* constraint): Given a path for national savings as a share of GDP $\{S_t/Y_t\}_{t=0}^{T-1}$ simply combine with a path for the current account balance $\{CAB_t/Y_t\}_{t=0}^{T-1}$ and use equation 8 to calculate I_t/Y_t. Then use steps 1–4 from sub-model 1 (section 2.1) to calculate growth. While equation 8 is almost trivially simple, it forces users to think through how investment will be funded. One common finding of the LTGM is that for plausible current account deficits, high investment rates require high domestic savings rates.

In sub-models 1 and 2 (*CAB/Y* constraint): A path for implied savings as: $S_t/Y_t = I_t/Y_t - CAB_t/Y_t$.

2.3.2 An external debt constraint

Alternatively, one can assume an external debt constraint combined with a path for foreign direct investment (FDI_t). From a simplified version of balance of payments identities, the CAB_t equals the acquisition of net foreign assets (NFA_t) less the incurrence of net foreign liabilities (NFL_t). Here, assets and liabilities are recorded end-of-period.

$$CAB_t = \Delta NFA_t - \Delta NFL_t \tag{9}$$

The change in net foreign liabilities can be decomposed into net inflows of FDI, as well as the accumulation of total external debt D_t (portfolio liabilities, public and private). For simplicity, we assume no changes in the stock of net foreign assets, which is a benign assumption for most developing countries.

$$\Delta NFL_t = FDI_t + (D_t - D_{t-1}) \quad \Delta NFA_t \approx 0$$

Substituting into equation 9, dividing by GDP (Y_t), and using $Y_t / Y_{t-1} = \left(1+g_{y,t}^{pc}\right)\left(1+g_{N,t}\right)$, one can write the CAB_t/Y_t as:

$$\frac{CAB_t}{Y_t}=-\left[\frac{D_t}{Y_t}-\frac{D_{t-1}/Y_{t-1}}{\left(1+g_{y,t}^{pc}\right)\left(1+g_{N,t}\right)}\right]-\frac{FDI_t}{Y_t} \tag{10}$$

Combining equations 8 and 10, calculate the investment implied by an external debt constraint and paths for national savings and FDI as in equation 11.

$$\frac{I_t}{Y_t}=\frac{S_t}{Y_t}+\frac{FDI_t}{Y_t}+\left[\frac{D_t}{Y_t}-\frac{D_{t-1}/Y_{t-1}}{\left(1+g_{y,t}^{pc}\right)\left(1+g_{N,t}\right)}\right] \tag{11}$$

Equation 11 states that investment can be funded by domestic savings, FDI, or external debt, where an increase in FDI_t/Y_t acts as a perfect substitute for national savings (S_t/Y_t). Equation 11 can be rearranged in terms of the savings rate implied by the external debt path, FDI, and investment.

$$\frac{S_t}{Y_t}=\left[\frac{I_t}{Y_t}-\frac{FDI_t}{Y_t}\right]-\left[\frac{D_t}{Y_t}-\frac{D_{t-1}/Y_{t-1}}{\left(1+g_{y,t}^{pc}\right)\left(1+g_{N,t}\right)}\right] \tag{12}$$

[18] For economies that are not open to capital flows, $CAB_t/Y_t \approx 0$, which implies $I_t/Y_t = S_t/Y_t$.

In sub-model 3 with an external debt constraint: Assume a path for external debt-to-GDP (D_t/Y_t), and paths for net inflows of foreign direct investment FDI_t/Y_t and domestic savings S_t/Y_t, and use equation 11 to calculate I_t/Y_t. Then use steps 1–4 from sub-model 1 (section 2.1) to calculate growth.

In sub-model 1 and 2 an external debt constraint: Combine paths for D_t/Y_t and FDI_t/Y_t with path for I_t/Y_t from sub-models 1 and 2 to generate implied savings using equation 12.

3. Understanding the drivers of growth

Now that we have derived the equations in the standard LTGM, it is important to try to understand the drivers of growth. As such, in this section we use log-linear approximations to get an analytical expression for growth.[19] First combine equations 2 and 3:

$$1+g^{pc}_{y,t+1}=[1+g_{\omega,t+1}][1+g_{\varrho,t+1}](1+g_{A,t+1})[1+g_{k,t+1}]^{1-\beta}[1+g_{h,t+1}]^{\beta}$$

Taking logs, and using the approximation $ln(1+x)\approx x$ (for small x) this becomes:

$$g^{pc}_{y,t+1}\approx g_{A,t+1}+g_{\omega,t+1}+g_{\varrho,t+1}+(1-\beta)g_{k,t+1}+\beta g_{h,t+1} \tag{13}$$

Taking logs of the capital per worker growth equation 5, yields:

$$ln(1+g_{k,t+1})=ln\left[1+\frac{I_t}{Y_t}/\frac{K_t}{Y_t}-\delta\right]-ln(1+g_{N,t+1})-ln(1+g_{\varrho,t+1})-ln(1+g_{\omega,t+1})$$

Applying the $ln(1+x)\approx x$ approximation (for small x):

$$g_{k,t+1}\approx\frac{I_t}{Y_t}/\frac{K_t}{Y_t}-\delta-g_{N,t+1}-g_{\varrho,t+1}-g_{\omega,t+1} \tag{14}$$

Combining equations 13 and 14 gives an expression for the determinants of growth:[20]

$$g^{pc}_{y,t+1}\approx g_{A,t+1}+\beta(g_{\omega,t+1}+g_{\varrho,t+1}+g_{h,t+1})+(1-\beta)\left[\frac{I_t}{Y_t}/\frac{K_t}{Y_t}-\delta-g_{N,t+1}\right] \tag{15}$$

The effect of most factors on growth in equation 15 depends on the labor share β, which averages around 0.5 across countries in PWT, but it is about 2/3 in Organisation for Economic Co-operation and Development (OECD) countries and the US, but much lower in many resource-rich countries. The exception is TFP growth ($g_{A,t+1}$) which has the largest direct effect on growth: a 1ppt increase in TFP growth increases growth by 1ppt (regardless of β). In contrast, a 1ppt increase in human capital growth ($g_{h,t+1}$,) labor force participation rate growth ($g_{\varrho,t+1}$), or working-age population share growth ($g_{\omega,t+1}$) increase per capita GDP growth by βppt. If $\beta\approx 0.5$, then a 1ppt increase in each of these factors, has *half* the effect as a 1ppt increase in TFP growth.

[19] Note that a quantitative analysis should be done using the exact equations above because even small approximation errors can compound over time.

[20] This log-linear expression follows that in Hevia and Loayza (2012) and in chapter 9, but with different notation.

Population growth ($g_{N,t+1}$) and depreciation (δ) reduce per capita GDP growth by $1-\beta$, because they reduce capital depth (capital per worker) by either reducing the amount of capital (δ) or increasing the number of workers ($g_{N,t+1}$).

In the final term of equation 15, the effect of an increase in the investment share of GDP depends on both the capital share $(1-\beta)$, as well as the existing capital-to-output ratio (K_t/Y_t). This term $(1-\beta)\frac{Y_t}{K_t}$ multiplying the investment share of GDP is of course the marginal product of capital (MPK). Assuming $1-\beta = 0.5$, a large 10ppt increase in the investment share of GDP (e.g., from 20% to 30%), raises growth by 2.5ppt per year if $K/Y = 2$ (i.e., $0.5 \times 0.1/2$), but only 1.25ppt if $K/Y = 4$. This means that an investment-led growth strategy, whereby the capital stock increases faster than GDP, will quickly become less effective over time as the capital-to-output ratio increases. A common recommendation of a LTGM analysis is that to ensure growth can be sustained, high investment rates must be accompanied by other reforms to boost productivity, human capital, or labor force participation to mitigate the increase in K/Y.

3.1 Growth in the very long run

The log-linear expression in equation 15 tracks year-to-year growth, but doesn't include dynamic feedback channels whereby noncapital growth drivers (TFP, human capital, demographics, and labor force participation) affect the future efficiency or quantity of investment.[21] While the analysis of steady states and balanced growth is not the focus of the LTGM, long-run relationships help to understand medium-run dynamics. To generate a long-run relationship, assume the capital-to-output ratio is fixed in the long run at $\bar{K}/\bar{Y}$ (one of the Kaldor's stylized facts, and also used in Kraay [2018], Pennings [2020], and Pennings [2022]).[22] In this case, GDP per capita from equation 1 can be rearranged as:

$$y^{pc} = A^{1/\beta}(\bar{K}/\bar{Y})^{(1-\beta)/\beta} h \; L/N$$

Taking logs:

$$\log(y^{pc}) = (1/\beta)\log(A) + [(1-\beta)/\beta]\log(\bar{K}/\bar{Y}) + \log(h) + \log(\rho) + \log(\omega)$$

One can use this equation to conduct some comparative statics on the level of GDP per capita (GDPPC) in the long run in response to one-time shocks to noncapital growth drivers. For example, consider a one-off increase in TFP growth at time t that permanently raised the *level* of TFP by 1% (relative to its pre-shock future path), but did not affect future TFP growth. By equation 15, this raises potential GDPPC in the short run by 1%, but it will raise the level of GDPPC in the long run by $(1/\beta)$%, which is much larger. The difference is that in the medium run, the higher level of TFP increases Y, which makes investment more effective (lower K/Y) and increases the quantity of investment (via a fixed I/Y). In the long run, a one-time 1% increase in human capital, the participation rate, or the working-age to total population ratio all lead to a 1% increase in GDPPC, which is $1/\beta$ larger than their short-run effects. A one-time increase in population also has no effect on long-run GDPPC, as the short-run negative impacts of higher population growth in equation 15 are offset by higher investment quantity and effectiveness in the medium–long run.

[21] For example, an increase in investment (TFP growth) today will boost growth, but will increase (reduce) the capital-to-output ratio tomorrow, making investment less (more) effective for growth. Any policy that increases growth today, will also increase the quantity of future investment in absolute terms, given the standard assumption that the investment share of GDP is fixed.

[22] One motivation of this is that it ensures a fixed MPK in the long run. In steady state, $\frac{K}{K} = \frac{I}{Y} \div (g_Y + \delta)$, so assumption can also be motivated by assuming constant GDP growth rate g_y and investment share of GDP along a balanced growth path. This also implies the expression above cannot be used to evaluate the effect of a permanent change in the investment rate.

3.2 Relation to the incremental capital output ratio (ICOR)

Although somewhat outdated, policy makers and commentators in a number of countries still use the (gross) ICOR as a measure of the effectiveness of investment in boosting growth.[23] The ICOR (or average ICOR) is the investment rate divided by headline GDP growth as in equation 16, which is used as a measure of how much investment is required to attain a given growth rate.[24] Implicit in the ICOR is the assumption that the investment rate and GDP growth rate are proportional.

$$ICOR = \frac{I_t}{Y_t} / g_{Y,\,t+1} \tag{16}$$

In the LTGM, the approximate relationship between GDP growth and I/Y is linear but not proportional, which means that the ICOR-type analysis only applies to an analysis of *extra* units of growth or investment, which we call the marginal ICOR ($ICOR_m$). Rearranging equation 15 above, one can get:

$$g_{y,t+t} \approx \tilde{g}_{y,t+t} + \frac{1-\beta}{K_t/Y_t} \times \frac{I_t}{Y_t} \tag{17}$$

where $\tilde{g}_{Y,t+t} = \beta g_{N,t+1} + g_{A,t+1} + \beta\left(g_{\omega,t+1} + g_{\varrho,t+1} + g_{h,t+1}\right) - (1-\beta)\delta$ is an intercept that doesn't depend on investment. In the LTGM, to boost GDP growth by 1%, one must raise the investment share of GDP by:

$$ICOR_{m,t} = \frac{1}{1-\beta}\frac{K_t}{Y_t} \tag{18}$$

The $ICOR_{m,t}$ can easily be calculated from model parameters; suppose $\beta = 0.5$ and $K_0/Y_0 = 2.2$, then the *marginal* ICOR is 4.4, so one needs to increase the investment share of GDP by 4.4ppts to boost headline GDP growth by 1%.

Critically, the marginal ICOR is *not* constant over time. An investment-led growth strategy will rapidly increase K/Y, leading to an *increase* in the marginal ICOR. This makes future investment less effective in boosting growth. In addition, the marginal ICOR will be different from the average ICOR in equation 16, because of the presence of the intercept $\tilde{g}_{Y,t+1}$.

Readers will note that the inverse of the marginal ICOR is just the *marginal product of capital (MPK)*: $MPK \equiv \frac{\partial Y_t}{\partial K_t} = (1-\beta)\frac{Y_t}{K_t} = \frac{1}{ICOR_{m,t}}$. The net return on capital is $R_t = MPK_t - \delta$. A rising marginal ICOR as K/Y increases during an investment-led growth program is the same as saying that the return to capital is falling.

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[23] For example, see FT columnist Martin Wolf's analysis of growth in India (March 1, 2005) and China (April 3, 2018).

[24] As the name suggests, the ICOR originally referred to net investment: $\frac{\Delta K_t}{\Delta Y_t} = \frac{I_t^{Net} / Y_{t-1}}{\Delta Y_t / Y_{t-1}} = \frac{(I_t - \delta K_{t-1})/Y_t}{\Delta Y / Y_t}$. However, in practice net investment was hard to measure in developing countries due to a lack of data on depreciation rates and capital stocks. As a result, many analysts approximated net investment with gross investment, giving the rule-of-thumb measure presented in equation 16. It should be noted that the rule-of-thumb gross ICOR is not the same as the original net ICOR: the net ICOR will be *smaller* by $\frac{\delta K_{t-1} / Y_t}{\Delta Y / Y_t}$, which could be important if growth rates are small. For example, with $K/Y = 2$ and $\delta = 0.05$, the net ICOR is smaller by 5 if GDP growth is 2%, but only by 2 if GDP growth is 5%.

4. Poverty module: the effect of growth on the poverty rate

The first goal of the World Bank is to end extreme poverty, and one of the main ways to reduce poverty is through faster economic growth. The poverty module, which is built into the standard LTGM spreadsheet (and the LTGM-PC spreadsheet) helps to calculate the effect of economic growth on poverty reduction.

The poverty rate is determined by the *distribution* of per capita income, as well as its average level. In the LTGM it is assumed that the natural log of income per capita follows a normal distribution, i.e., $ln(y^{pc}) \sim N(\mu, \sigma^2)$.[25] The log-normal income distribution greatly simplifies the calculation of poverty rates, requires very few parameters or data, and empirically is a good approximation of most of the income distribution; see Lopez and Serven (2006) and Bourguignon (2007). The addition of the poverty module does not affect the workings of sub-models 1–3 above as, for simplicity, the poverty rate is assumed not to affect the Solow growth fundamentals.

The poverty headcount rate P is the proportion of people with incomes below the poverty line L. Combined with the mean μ and standard deviation σ of the *underlying* normal distribution (not the mean or standard deviation of the *actual* income distribution), the poverty rate can be calculated from the standard normal cumulative density function (CDF) as in equation 19.[26]

$$P_t = \Phi\left(\frac{lnL - \mu_t}{\sigma_t}\right) \tag{19}$$

For a log-normal distribution, the Gini coefficient of income inequality G, is a transformation of standard deviation σ of the *underlying* normal distribution:

$$G_t = 2\Phi\left(\frac{\sigma_t}{\sqrt{2}}\right) - 1 \tag{20}$$

To calculate μ_t from data on P and L, invert equation 19:

$$\mu_t = lnL - \sigma_t \Phi^{-1}(P_t) \tag{21}$$

where σ_t can be calculated from G_t by inverting equation 20:

$$\sigma_t = \sqrt{2} \times \Phi^{-1}\left(\frac{G_t + 1}{2}\right) \tag{22}$$

The mean income (GDP per capita) is given by $exp(\mu + \sigma^2/2)$.[27] Absent any change in income inequality (i.e., with constant G and σ), economic growth shifts the whole income distribution to the right (proportionately) by increasing μ. Allowing for a change in inequality, the per capita growth rate is given by equation 23:

$$\begin{aligned} 1 + g^{pc}_{y,t+1} &= \bar{y}^{pc}_{t+1} / \bar{y}^{pc}_t = \frac{exp\left(\mu_{t+1} + \sigma^2_{t+1}/2\right)}{exp\left(\mu_t + \sigma^2_t/2\right)} \\ &= exp\left(\mu_{t+1} - \mu_t + \frac{1}{2}\left(\sigma^2_{t+1} - \sigma^2_t\right)\right) \end{aligned} \tag{23}$$

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[25] Thanks to Aart Kraay for suggesting this approach. Although the distribution of income is always log normal, μ and σ vary across countries and over time.

[26] The CDF (proportion less than x) is $Pr(X \leq x) = \Phi(x)$, which is *normsdist*(x) in Excel. The inverse function $\Phi^{-1}(Pr)$ is *normsinv*(Pr) in Excel.

[27] This is just the mean of a variable X if $\ln(X)$ (not X) is normally distributed with mean μ and deviation σ.

We can rewrite this as equation 24, which is used to update the mean of the underlying normal distribution in sub-models 1 and 3.

$$\mu_{t+1} = ln\left(1+g_{y,t+1}^{pc}\right)+\mu_t - \frac{1}{2}\left(\sigma_{t+1}^2 - \sigma_t^2\right) \quad (24)$$

Using the approximation $ln(1 + g) \approx g$ (for small g), this becomes: $\mu_{t+1} \approx g_{y,t+1}^{pc} + \mu_t - 1/2\left(\sigma_{t+1}^2 - \sigma_t^2\right)$ which suggests that with constant income inequality ($\sigma_{t+1}^2 = \sigma_t^2$), an extra percentage point of per capita GDP growth increases μ by one percentage point.

Steps to solve for poverty rates in sub-models 1, 2, and 3 using the log-normal distribution

In sub-models 1 and 3, growth fundamentals (investment, savings, etc.) determine the path of per capita growth $\{g_{y,t+1}^{pc}\}$, from which we calculate the change in the poverty rate. In sub-model 2 the path of growth is set exogenously.[28] The steps are as follows:

1. Assume a path for the Gini coefficient on income $\{G_t\}$ from the first period until the end of the simulation (this could also be a constant Gini coefficient), and then calculate σ_t for each year using equation 22.[29]
2. Choose an initial poverty line L and initial headcount poverty rate P_t at that poverty line. The pre-loaded defaults are the international extreme poverty line (US$1.90/day 2011 PPP), and the extreme poverty rate for the most recent household survey in PovcalNet. Alternatively, users can manually enter their own $\{P,L\}$ for the national poverty line (which is often quite different).[30] Calculate the initial μ_t using equation 21.[31]
3. For each period after the first, update μ_{t+1} using equation 24.
4. For each period after the first, calculate the poverty rate P_{t+1} using equation 19 (given μ_{t+1}, σ_{t+1} and L).[32]

4.1 The growth elasticity of poverty: a measure of the effect of growth on poverty

In the literature, the *growth elasticity of poverty (GEP)* ε_p is the percentage fall in the headcount poverty rate (e.g. poverty rate of 26% → 25.74% is a 1% fall) from a 1% increase in per capita income (i.e., from a 1% per capita growth rate). For a log-normal distribution, the GEP is given by equation 25, which helps the LTGM user to compare their estimates with those in the empirical literature.[33] Bourguignon (2007) reports empirical estimates of about $\varepsilon_p \approx 1.5$ across poverty spells, though several earlier papers estimate a GEP of 2 or even 3.

However, the GEP varies substantially across countries and over time. With a log-normal income distribution, the GEP is often higher for countries with *low* rates of poverty, because even a small change

[28] It is also possible to set a path for poverty in sub-model 2, and then calculate required investment to achieve it. In practice, required investment rates were unstable, so this option is disabled by default in the LTGM sheet.

[29] This can be done in Excel as $\sigma_t = sqrt(2) * NORMSINV\ (0.5 * (G_t + 1))$.

[30] It is only the initial poverty rate P that affects the model. Changes in L (for example changing from per-day to per month, or the currency of measurement), do not affect the model as μ scales accordingly.

[31] This can be done in Excel as $\mu_{i,t} = ln(L_i) - \sigma_{i,t}\ NORMSINV\ (P_{i,t})$.

[32] This can be done in Excel as $P_{t+1} = NORMSDIST((\ln(L) - \mu_{t+1}) / \sigma_{t+1})$.

[33] An increase in average income (keeping σ constant) always reduces the poverty rate, so we follow Bourguignon (2007) and make the elasticity positive by pre-multiplying by −1. The second equality in equation 25 comes from the mean of a log-normal distribution $\ln \overline{y}_i = \mu_i + \sigma_i^2 / 2$ (keeping σ_i constant) and the third equality comes from applying Leibniz's rule to equation 19. This equation is similar to equation 3′ in Bourguignon (2007). Here $\phi(.)$ is the normal probability distribution function (in Excel $NORMSDIST(x, 0, 1, FALSE)$ and equation 25 is $(1/\sigma_{t+1}) * NORMDIST\ ((ln(L) - \mu_{t+1})/\sigma_{t+1}, 0, 1, FALSE)/ NORMSDIST\ ((\ln(L) - \mu_{t+1})/\sigma_{t+1})$.

in the poverty headcount is large as a percentage of a very small base. The GEP is also higher in countries that are more equal (a smaller Gini coefficient of income). As noted by Bourguignon (2007), this means that a reduction in inequality has a "double dividend": first it reduces poverty in and of itself, and second it increases the growth elasticity of poverty.

$$\varepsilon_{p,t} \equiv -\frac{\partial lnP_t}{\partial \ln \bar{y}_t} = -\frac{\partial P_t}{\partial \mu_t}\frac{1}{P_t} = \frac{1}{\sigma_t}\frac{\phi\left(\frac{lnL-\mu_t}{\sigma_t}\right)}{\Phi\left(\frac{lnL-\mu_t}{\sigma_t}\right)} \tag{25}$$

A closely related metric is *growth semi-elasticity of poverty*, which is defined here as the *percentage point* change in poverty (e.g., a poverty rate of 26% → 25% is a 1ppt fall) for an extra 1% increase in per capita income (i.e. from a 1% per capita growth rate) as in Equation 26—which is often more relevant than the GEP for policy makers. Both the GEP and *growth semi-elasticity of poverty* are calculated as memorandum items in LTGM spreadsheets.

$$\Delta_p \equiv -\frac{\partial P_t}{\partial \ln \bar{y}_t} = \varepsilon_{p,t} \times P_t = \frac{1}{\sigma_t}\phi\left(\frac{lnL-\mu_t}{\sigma_t}\right) \tag{26}$$

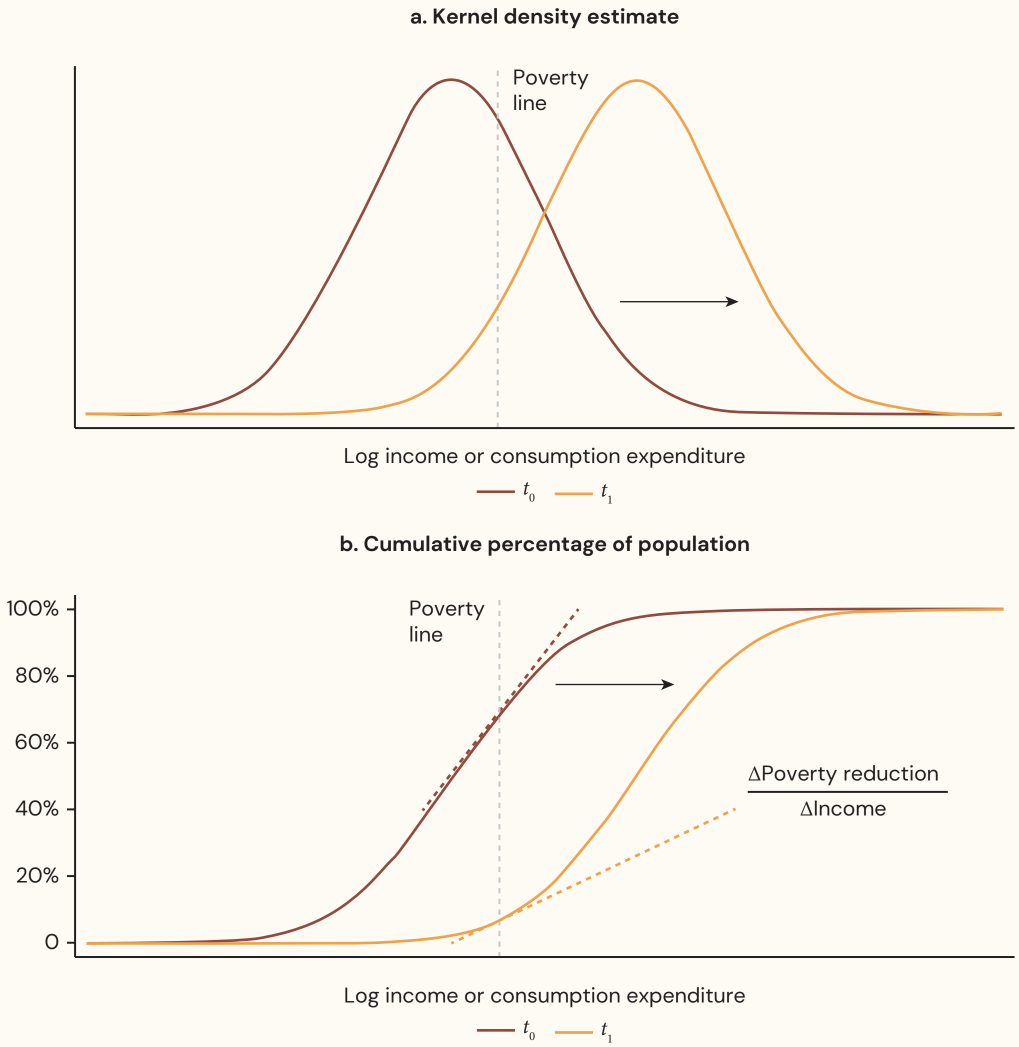
<u>Understanding the effect of growth on poverty</u>

Figure 1.1 shows an example of how growth affects poverty in the LTGM—the figure is reproduced from World Bank (2015). Panel a shows the distribution of the fraction of people with different incomes—a bell curve—plotted against log per capita income.[34] The fraction of people that are poor is integral to the left of the poverty line. In panel b is the cumulative income distribution (CDF, fraction of the population with incomes below each number on the x-axis), where the poverty rate can be read off the y-axis. We start at time t_0 with the red income distribution. Economic growth (with unchanged inequality) between periods t_0 and t_1 raises all incomes proportionately so the curve shifts to the right, yielding the orange income distribution. One can see that the integral to the left of the poverty line in panel a is now smaller: economic growth has led many people's incomes to shift across the poverty line, reducing the poverty rate. Likewise, the CDF in panel b has a lower poverty rate on the y-axis (orange line).

The effect of growth on poverty (measured by the semi-elasticity) is represented by the height of panel a just to the left of the poverty line. This measures the fraction of people that will move across the poverty line for a small increase in incomes. This semi-elasticity is also represented by the slope of the CDF in panel b. One can see that the growth semi-elasticity of poverty is inverse-U shaped in the poverty rate, with the largest response of poverty rates in *percentage points* generally occurring in countries with a poverty rate of around 0.5 (when the poverty line hits the top of the bell curve in panel a). At this point there are many people just below the poverty line who can be moved out of poverty by a small increase in income (and the CDF in panel b is the steepest). The rate of poverty reduction (in ppts) and the growth semi-elasticity of poverty will change over time, even with unchanged inequality and unchanged per capita growth, because the fraction of the population near the poverty line will change. For example, in figure 1.1, the fraction of people just below the poverty line in panel a is lower at t_1 than t_0 (and the slope of the CDF in panel b is shallower), indicating a lower growth semi-elasticity of poverty at t_1 than t_0. Also note that at lower levels of inequality (a lower Gini/lower σ, and keeping other things equal), the income distribution in panel a becomes more compressed, raising the fraction of people just to the left of the poverty line and increasing the growth semi-elasticity of poverty.

[34] More specifically, this is a kernel density estimate of the probability distribution function (PDF) of poverty. As per capita income is log normally distributed in the LTGM, then the PDF of log of per capita income is just a normal distribution.

Figure 1.1: **The Effect of Growth on Poverty (with unchanged inequality)**



Source: Reproduced from World Bank (2015) Figure 1.4.

GEP implementation in the LTGM spreadsheet: In the LTGM, users can input their own GEP instead of using the one implied by the log-normal income distribution (equation 25). For sub-model 1, sub-model 3, and sub-model 2 (with a non-poverty target), the poverty rate is given by:

$$P_{t+1} = \left(1 - \varepsilon_{p,t+1} \times g^{pc}_{y,t+1}\right) P_t \tag{27}$$

Alternatively, required per capita growth to achieve a poverty rate of P_{t+1} (given P_t and $\varepsilon_{p,t+1}$):[35]

$$g^{pc}_{y,t+1} = -\left(P_{t+1} / P_t - 1\right) / \varepsilon_{p,t+1} \tag{28}$$

4.2 Shared prosperity premium (SPP)

One of the goals of the World Bank is to "Promote shared prosperity by fostering the income growth of the bottom 40% for every country." In the LTGM poverty module, the average income of the bottom 40% of

[35] It is also possible to set a path for poverty in sub-model 2, and then calculate required investment to achieve it. In practice, required investment rates were unstable, so this option is disabled by default in the LTGM spreadsheet.

the population is given by equation 29, where $k_t \equiv \exp(\sigma_t \Phi^{-1}(0.4) + \mu_t)$ is the income cutoff that defines the bottom 40% (which changes over time and across countries).[36]

$$E\left(y^{pc} \mid y^{pc} < k_t\right) = 0.4^{-1} e^{\mu + \sigma^2/2} \Phi\left(\Phi^{-1}(0.4) - \sigma_t\right) \tag{29}$$

The income share of the bottom 40% of the population ($SB40$) can be expressed as[37]

$$\begin{aligned} SB40_t &\equiv \frac{E\left(y^{pc} \mid y^{pc} < k_t\right) \times 0.4}{\overline{y}_t^{pc}} \\ &= \frac{0.4^{-1} e^{\mu_t + \sigma_t^2/2} \Phi\left(\Phi^{-1}(0.4) - \sigma_t\right) \times 0.4}{e^{\mu_t + \sigma_t^2/2}} \\ &= \Phi\left(\Phi^{-1}(0.4) - \sigma_t\right) \end{aligned} \tag{30}$$

In terms of the Gini coefficient (using equation 22) the income share of the bottom 40% can be written as:

$$SB40_t = \Phi\left(\Phi^{-1}(0.4) - \sqrt{2} \times \Phi^{-1}\left((G_t + 1)/2\right)\right) \tag{31}$$

As such, the growth rate of average income of the bottom 40% is defined as the average income gross growth rate $1 + g^{pc}_{\overline{y},t+1}$ times the gross growth rate of the income share of the bottom 40% ($SB40_{t+1}/SB40_t$)

$$\begin{aligned} 1 + g_{\overline{40},t+1} &\equiv \frac{E\left(y^{pc}_{t+1} \mid y^{pc}_{t+1} < k_{t+1}\right)}{E\left(y^{pc}_t \mid y^{pc}_t < k_t\right)} \\ &= \left(1 + g^{pc}_{\overline{y},t+1}\right) \frac{\Phi\left(\Phi^{-1}(0.4) - \sigma_{t+1}\right)}{\Phi\left(\Phi^{-1}(0.4) - \sigma_t\right)} \\ &= \left(1 + g^{pc}_{\overline{y},t+1}\right) \frac{SB40_{t+1}}{SB40_t} \end{aligned} \tag{32}$$

where $g^{pc}_{\overline{y},t+1}$ is the economy-wide per capita growth rate as defined in equation 23, and σ is the SD of the underlying normal distribution (which is a one-to-one transformation of the Gini coefficient by equation 20).

The *Shared Prosperity Premium (SPP)* (equation 33) is the excess income growth of the bottom 40% ($g_{\overline{40},t+1}$) over the average per capita growth rate of the whole economy $\left(g^{pc}_{\overline{y},t+1}\right)$:

$$SPP_{t+1} \equiv ln\left(1 + g_{\overline{40},t+1}\right) - ln\left(1 + g^{pc}_{\overline{y},t+1}\right) \approx g_{\overline{40},t+1} - g^{pc}_{\overline{y},t+1} \tag{33}$$

Combining equations 33 and 32, one can see an expression for the SPP_{t+1}, which is just the log growth rate of income share of the bottom 40%.

$$SPP_{t+1} = \ln\left[\frac{\Phi\left(\Phi^{-1}(0.4) - \sigma_{t+1}\right)}{\Phi\left(\Phi^{-1}(0.4) - \sigma_t\right)}\right] \tag{34}$$

$$= \ln\left[\frac{SB40_{t+1}}{SB40_t}\right] \tag{35}$$

[36] This follows from the expression for a conditional mean of a log-normal distribution:
$E(X \mid X < k_t) = e^{\mu + \sigma^2/2} \Phi\left(\frac{ln(k_t) - \mu_t - \sigma_t^2}{\sigma_t}\right) \Big/ \Phi\left(\frac{ln(k_t) - \mu_t}{\sigma_t}\right)$, where $\Phi\left(\frac{ln(k_t) - \mu_t}{\sigma_t}\right) = 0.4$.

[37] To see this, we normalize the population to 1, which means that the mean per capita income $\overline{y}^{pc}$ equals total income.

From equation 34 one can see that when there is no change in income inequality (such that $\sigma_{t+1} = \sigma_t$ and $G_{t+1} = G_t$), then the shared prosperity premium will be zero, and the growth rate of the incomes of the bottom 40% will be the same as the per capita growth rate of the economy as a whole (recall from equation 22 that $\sigma_t = \sqrt{2} \times \Phi^{-1}\left([G_t + 1]/2\right)$). As such, if income follows a log-normal distribution, then there is a one-to-one relationship between the change in inequality (as measured by the Gini coefficient) and the shared prosperity premium: a fall (raise) in inequality is equivalent to a positive (negative) shared prosperity premium.

Shared prosperity implementation in the LTGM spreadsheet: Given equation 34, the Shared Prosperity Premium enters the LTGM as an alternative way for the user to specify the path of inequality, or to summarize the implications for the bottom 40% of a given path of Gini coefficient. As such, the shared prosperity mostly enters in the sheet InputdataA when the user is specifying the path for inequality (and the SPP is plotted in *GraphsA*).[38]

- If the user specifies a path for the Gini coefficient, then the implied Shared Prosperity Premium is calculated using equation 34 as a residual (using equation 22 to substitute out for the Gini as an intermediate step).
- If the user specifies a path for the SPP:
  - the user must still specify an initial Gini coefficient G_t for the first year, which is then converted into an initial σ_t using equation 22.
  - σ_{t+1} given by equation 36, where a higher *SPP* reduces σ_{t+1}

$$\sigma_{t+1} = \Phi^{-1}(0.4) - \Phi^{-1}\left[e^{SPP_{t+1}}\Phi\left(\Phi^{-1}(0.4) - \sigma_t\right)\right] \tag{36}$$

  - the Gini coefficient G_{t+1} (which enters the model spreadsheets) is calculated using equation 20.
- The income share of the bottom 40% of the population (*SB*40) is recorded as a memorandum item using equation 30.

5. Conclusions

This chapter has provided a description of the standard Long Term Growth Model (LTGM), which includes three sub-models in the spreadsheet-based tool, a module that connects growth and poverty, and some intuition about how the model works. For how the standard LTGM is applied in practice, the chapters in part 3 of this volume provide some examples.[39]

One of the main advantages of the standard LTGM is its simplicity and transparency—which allow it to be solved in a spreadsheet (without macros)—but simplicity and transparency also have costs. One of those costs is that future paths for growth drivers are exogeneous in the model. While this is necessary for simplicity and flexibility, and to enable the model to be solved in a spreadsheet, it limits the scope of interactions between different growth drivers and the scope of policies to affect growth fundamentals (for example, for investment to respond to taxation). Many other models in the growth literature relax these assumptions, at the cost of complexity (among other things). In a standard Ramsey (1928)–Cass (1965)–Koopmans (1965) neoclassical growth model, the investment/savings rate is endogenous as households choose consumption and savings to maximize utility. In Romer (1990), Aghion and Howitt (1992), and others, the TFP growth rate is endogenized through research and development and creative destruction.

[38] The income growth of the bottom 40% in each of Model 1/1s/2/2s/3/3s is also summarized at a poverty memorandum item at the bottom of each of those sheets and plotted in *GraphsB*.

[39] Chapters 5 and 8 in Part 3 use the LTGM-PC rather than the standard LTGM, but how to calibrate and use the models are similar.

In Lucas (1988) human capital accumulation is endogenous. Galor and Weil (1996), and others, model the two-way interaction between fertility and economic growth. Other papers in the growth literature build upon these early contributions.

Nonetheless, there are a number of ways that the basic model can be enhanced to respond to criticisms, add functionality, and enhance realism without sacrificing simplicity and a spreadsheet-based setup. These are explored in a number of extensions, including those later in this volume and a work in progress. One of these criticisms is that there is no separate role for infrastructure or natural resources in the production function (equation 1) despite the fact that much of the development discussion revolves around infrastructure, and many developing countries export commodities. These concerns are addressed in extensions in chapters 2 and 4 respectively. Another common criticism is that TFP growth is exogenous, which is particularly problematic given its importance as a driver of long-run growth. The TFP extension in chapter 3 seeks to unpack the deeper determinants of TFP growth, which can then be used as an input into the standard LTGM spreadsheet. Finally, the traditional concept of human capital based on the years of schooling misses important adjustments for schooling quality (Filmer et al. 2018) and health (Weil 2007). A human capital extension, in a "beta version" at the time of writing (and so not included in this volume), translates these broader measures of human capital in the World Bank Human Capital Index (Kraay 2018) for use as an LTGM input. Future work extending the LTGM to multiple sectors (especially agriculture) and incorporating the effects of climate change are planned.

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Chapter 2

Assessing the Effect of Public Capital on Growth: An Extension of the World Bank Long Term Growth Model[1]

Sharmila Devadas and Steven Pennings[2]

Abstract

To analyze the effect of an increase in the quantity or quality of public investment on growth, this paper extends the World Bank's Long Term Growth Model (LTGM), by separating the total capital stock into public and private portions, with the former adjusted for its quality. The paper presents the Long Term Growth Model Public Capital Extension (LTGM-PC) and accompanying freely downloadable Excel-based tool. It also constructs a new Infrastructure Efficiency Index (IEI), by combining quality indicators for power, roads, and water as a cardinal measure of the quality of public capital in each country. In the model, public investment generates a larger boost to growth if existing stocks of public capital are low, or if public capital is particularly important in the production function. Through the lens of the model and utilizing newly collated cross-country data, the paper presents three stylized facts and some related policy implications. First, the measured public capital stock is roughly constant as a share of gross domestic product (GDP) across income groups, which implies that the returns to new public investment, and its effect on growth, are roughly constant across development levels. Second, developing countries are relatively short of private capital, which means that private investment provides the largest boost to growth in low-income countries. Third, low-income countries have the lowest quality of public capital and the lowest efficient public capital stock as a share of gross domestic product. Although this does not affect the returns to public investment, it means that improving the efficiency of public investment has a sizable effect on growth in low-income countries. Quantitatively, a permanent 1ppt GDP increase in public investment boosts growth by around 0.1–0.2ppts over the following few years (depending on the parameters), with the effect declining over time.

JEL: O40, O57, H41.
Keywords: Long term growth, infrastructure, public capital, public investment efficiency.

[1] **Editors' note:** This chapter is a reprint of World Bank Policy Research Working Paper WPS 8604, originally published in October 2018. The appendices and spreadsheet-based LTGM-PC tool are available at the Long Term Growth Model website: https://www.worldbank.org/LTGM. Sharmila's affiliation is based on when the article was written, not her current affiliation.

[2] Sharmila Devadas and Steven Pennings, World Bank. Corresponding author email: spennings@worldbank.org. The views expressed here are the authors', and do not necessarily reflect those of the World Bank, its Executive Directors, or the countries they represent. The authors are grateful to Norman V. Loayza for guidance, Luis Serven for helpful comments, and Jorge Luis Guzman for research assistance. The authors also thank the Global Facility for Growth for Development Trust Fund, supported by the Republic of Korean government, for financial support.

1. Introduction

Inadequate infrastructure, especially public infrastructure, is often viewed as a key impediment to economic growth and development in low- and middle-income countries. While increasing infrastructure investment has been a part of national development strategies for decades, its perceived importance has gained prominence with the rapid development of China and its infrastructure-led growth strategy, as well increased infrastructure-specific finance through new bilateral lending, the Asian Infrastructure Bank, and the Belt and Road Initiative.

Despite the importance of public infrastructure investment, there is wide disagreement about the size and significance of its effect on growth in developing countries (Calderon and Serven 2014). On one hand, the needs are clearly great—close to 700 million people do not have access to safe drinking water and 1.2 billion are without electricity—and so one should expect a sizable impact.[3] Several papers have estimated large returns to infrastructure investment—most frequently cited, Aschauer (1989). But as infrastructure investment is endogenous – for example, growth for other reasons might generate public revenues which allows the construction of infrastructure—many of those empirical studies lack causal validity and estimated impacts are implausibly large. Many other papers have found insignificant or negative impacts (Bom and Ligthart 2014), possibly because public investment in developing countries often fails to generate productive capital due to corruption and the presence of "white elephants" (Pritchett 2000).

Perhaps less appreciated is that there is a great deal of confusion in the empirical and policy discussion about the dynamics and mechanisms through which public infrastructure investment would affect growth. For example, empirical studies (and policy reports) are often vague about whether it is the level of infrastructure that affects growth, or whether infrastructure investment (and hence changes in infrastructure levels) affects growth. Likewise, empirical studies often have difficulty estimating *when* the boost to growth might occur (whether the size of the effect will increase or decrease over time) and what country-level factors determine the impact on growth (as different studies are for particular countries or reflect a cross-country average). All these aspects are crucial for evaluating the effectiveness of a country's public investment–led growth plans.

This chapter makes contributions in two areas to try to address these gaps. First, we develop a model of the effect of public investment on long term growth— called the Long Term Growth Model Public Capital Extension (LTGM-PC)— that is simple enough to be solved in an Excel spreadsheet without macros (which is provided as a companion to this chapter on the website www.worldbank.org/LTGM).[4] Unlike coefficients estimated in most empirical studies, the LTGM-PC allows for the effect of extra public investment to vary across countries and over time within the same country. In the model, the effect of an increase in public investment (or the quality of that investment) and the full dynamic growth path depend on country-specific factors such as the scarcity of public capital (relative to gross domestic product [GDP]) and some crowding in of private investment. The model also allows for the fact that the public capital stock might be of low-quality construction, which is a practical concern in many developing countries.

More technically, our model builds on the celebrated Solow-Swan growth model and another World Bank Excel-based tool known as the Long Term Growth Model (LTGM), which is described in Chapter 1 of this volume, which we refer to as the Standard LTGM. However, in the Solow-Swan model (and Standard LTGM), capital is simply an aggregate, and so those models cannot simulate the specific effect of an increase

[3] http://www.worldbank.org/en/news/feature/2016/04/16/spending-more-and-better-essential-to-tackling-the-infrastructure-gap.

[4] The relevant data and parameters for all countries are already preloaded into the LTGM-PC spreadsheet.

in public investment. In contrast, in the LTGM-PC, total capital is split into public and private portions. The LTGM-PC retains many other realistic growth drivers and features of the Standard LTGM, including other growth fundamentals (human capital, total factor productivity [TFP], demographics, labor market participation by gender), and also the implications for poverty rates. Section 2 presents the model and section 3 describes how it is implemented in the Excel-based tool.

Despite being theoretical, the chapter draws extensively on the empirical literature to guide the choice of parameters. The most important parameter is the elasticity of output to public capital, ϕ, which we call the *usefulness* of public capital. In section 5 we review the evidence from two meta-analyses and other literature, which suggests an elasticity of up to $\phi = 0.17$ for essential infrastructure and $\phi = 0.10$ for generic public capital like buildings (though users can also specify its value). We also calculate the country-specific scarcity of public capital using a new public capital database from the International Monetary Fund's (IMF's) Fiscal Affairs Department.

However, we could not find a suitable measure of the fraction of public capital that is of high quality (we use "efficiency" and "quality" interchangeably).[5] So in section 4 we develop a new cardinal Infrastructure Efficiency Index (IEI) to quantify the extent to which public capital is of high quality in different countries. The IEI is based on estimates of the fraction of roads that are in poor condition, water that never reaches its final customers, and electricity that is lost through transmission and distribution.

Our second contribution is to document how the quantity and quality of public capital vary across countries with different levels of development, and how this affects the impact of new public and private investment on growth (section 6). This analysis is conducted through the lens of the LTGM-PC and utilizes the cross-country data on the IEI and public capital stocks collected for the Excel-based tool.

Surprisingly, we find that the effect of an extra 1ppt of GDP of public investment on growth is roughly constant across different levels of development.[6] This puts us at odds with optimistic commentators claiming that sizable "infrastructure gaps" mean a larger growth dividend from public investment in low-income countries. But it also puts us at odds with pessimistic commentators who claim that the low efficiency of public investment in developing countries—due to corruption and mismanagement, for example—means that such projects have little effect on growth.[7] Overall a 1ppt increase in public investment as a share of GDP increases growth by 0.1–0.2ppts in our model, depending on the calibration. As public investment is typically around 5% of GDP and usually less than 10% of GDP, higher public investment alone cannot turn a slow-growing country into a tiger economy.

Instead, developing countries are short of *private* capital, both relative to GDP and in absolute terms. Private capital as a share of GDP in low-income countries is only two-thirds of that in middle-income countries, and almost one-half that in high-income countries. By our calculations, this means the return to private capital is highest in low-income countries, relative to both advanced countries and also relative to the return on public capital. This stems from the relatively low levels of private investment in low-income countries (whereas public investment in low-income countries is actually larger as a share of GDP).

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[5] Other indices like the World Economic Forum's infrastructure quality index or the IMF Public Investment Efficiency Index (PIE-X) include survey-based scores or distance to the frontier analysis, which means that a quality or efficiency score does not reflect the cardinal or absolute fraction of public capital operating as it should (see section 4). The literature uses the terms quality and efficiency interchangeably as well.

[6] This result follows from measured public capital as a share of GDP being roughly constant across countries with different levels of development, which is possibly overstated in low-income countries with weak governance (Keefer and Knack 2007).

[7] As in Berg et al. (2015), the level of efficiency in the LTGM-PC has no effect on the return to new public investment because the low quality of new public investment is exactly offset by a greater need for public capital due to the poor quality of past public investment. See sections 2 and 6.5.

However, low-income countries also have the most inefficient public investment—with an infrastructure efficiency index one-fifth lower than middle-income countries and one-third lower than high-income countries. Even though low-income countries might not be short of *measured* public capital—as public investment is likely overstated in many low-income countries with poor institutions (Keefer and Knack 2007)—low-income countries are likely short of *efficient* public capital that is actually useful in production. This means that in low-income countries: (i) the marginal product of efficient public capital—if it could be installed—is extremely high, and (ii) there is substantial room for low-income countries to boost growth through increases in efficiency. As high efficiency only affects output through new investment, countries with high existing rates of public investment (and low existing efficiency) have the most to gain. However, efficiency is extremely difficult to increase quickly, and so in practical terms the return to public investment will still be similar across different levels of development (as claimed above).

1.1 Definitions and related literature

In this chapter, we generally equate public capital with infrastructure for simplicity, though we recognize that not all public capital is infrastructure, and not all infrastructure is public. Public capital in the literature is defined as *core* infrastructure made up of transport (roads, railways, airports) and utilities (water supply and sanitation, energy, information and communication technology [ICT]; but also hospitals, education buildings, other public buildings and public physical assets (Agenor 2013, Bom and Ligthart 2014).[8] Although the public sector dominates the provision of infrastructure in low- and middle-income countries, in high-income countries the private sector plays an increasingly important role, including in hybrid categories like public-private partnerships, or PPPs (IMF 2015). In the literature, infrastructure is generally thought to increase the productivity of private factors much like TFP; see for instance Romp and de Haan (2007); Serven (2010); and Straub (2008)—an approach we take here.

The closest modeling project to ours is the IMF's Debt, Investment and Growth (DIG) Model (Buffie et al. 2012). While the DIG model seeks (in part) to estimate the effect of infrastructure on growth, it also aims to provide more analysis on the fiscal side on how public infrastructure might be financed. The DIG model also accounts for traded and nontraded goods and optimizing consumers (among other things). While the fiscal analysis and other features of the DIG model are missing from the LTMG-PC, the cost of those extra features is in complexity and transparency: for example, the DIG model cannot be solved in a standard Excel spreadsheet. Our default calibration of the usefulness of public capital $\phi = 0.17$, is the same as that used in the the DIG model. The LTGM-PC and the DIG model in turn build on an earlier generation of models involving public capital, such as Baxter and King (1993) and Barro and Sala-i-Martin (1992) and more recent models like Leeper et al. (2010).

2. A model of long term growth with public capital

In this section, we provide an overview of the model structure (sections 2.1–2.3) and some intuition on growth drivers (section 2.4). Section 3 describes how these model equations enter the LTGM-PC Excel-based tool that enables users to run policy simulations.

[8] IMF (2015): Public capital is the accumulated value of public investment over time, which is the principal input into the production of public infrastructure, comprising *economic* infrastructure (transport and utilities) and *social* infrastructure (public schools, hospitals and prisons).

2.1 The production function

To analyze the effects of public capital on growth, we adapt the Standard LTGM by splitting aggregate capital stock into public and private portions. We assume a Cobb-Douglas specification, where the two capital stocks have unitary elasticity of substitution, in contrast to being perfect substitutes in the Standard LTGM.[9] Based on the models in Eicher and Turnovsky (2000) and Agenor (2013), we first consider the following production function at time *t*:

$$Y_t = A_t S_t (K_t^P)^{1-\beta} (h_t L_t)^{\beta} \tag{1}$$

Each firm takes technology (TFP), A_t, and public services, S_t, as given, that is, these are externalities to the firm. K_t^P is the private capital stock, $h_t L_t$ is effective labor, which can be further decomposed into h_t, human capital per worker, and L_t, the number of workers. $1-\beta$ and β are private capital and labor income shares. Next, we consider the following specification for public services S_t:

$$S_t = \left[\frac{G_t}{K_t^{P\zeta}} \right]^{\phi} \tag{2A}$$

G_t is the efficient physical public capital stock—the public capital that is actually used in production. ζ captures whether public capital is subject to congestion (or not)—discussed further below. ϕ is the *usefulness* of public capital (more technically the elasticity of output to efficient public capital).

$$G_t = \theta_t K_t^{Gm} \tag{2B}$$

Due to corruption, mismanagement, or pork-barreling, only a fraction $\theta_t \leq 1$ of measured public capital is useful for production. The measured capital stock K_t^{Gm} is what is recorded in international statistical databases, and constructed using the perpetual inventory method. θ_t is the average *efficiency/quality* of the public capital stock. Equations (1), (2A), and (2B) can be written in a more conventional production function as:

$$Y_t = A_t \left(\theta_t K_t^{Gm} \right)^{\phi} (K_t^P)^{1-\beta-\zeta\phi} (h_t L_t)^{\beta} \tag{3}$$

Congestion ($\zeta \in [0,1]$)

In principle, the congestion parameter in equations (2A) and (3) can take values between: $\zeta = 1$ (full congestion) and $\zeta = 0$ (no congestion). As long as $\zeta > 0$, it is the *ratio* of public capital to private capital that provides public services, rather than the absolute amount of public capital (Barro and Sala-i-Martin 1992).[10] When there is a large amount of private capital relative to public capital, the public capital becomes "congested" and its benefits diminish. The intuition for this is a road network: when there are too many cars on the road, it becomes jammed, reducing its capacity to add to output.

In the Excel-based tool, we only allow for two cases, $\zeta \in \{0,1\}$ for simplicity. In our main "congestion" specification, $\zeta = 1$. This means that K_t^{Gm} must grow faster than K_t^P to have a positive effect on output. In this scenario, there are decreasing returns to scale to private inputs (private capital and effective labor),

[9] See appendix A1.5 for a general idea of how the Standard LTGM differs from the LTGM-PC.

[10] Congestion can also be measured in terms of both private capital and labor supply (see for instance Glomm and Ravikumar [1997]) or aggregate output, but these do not result in substantial changes to the analysis (Eicher and Turnovsky 2000). Aside from absolute congestion, there can also be relative congestion, in which case, congestion increases only if aggregate usage increases relative to individual usage. See Eicher and Turnovsky (2000) for further details on how relative and absolute congestion affect growth analysis.

and constant returns to scale to all inputs. In the appendix (available on the website www.worldbank.org/LTGM) and in some parts of the chapter we take the alternative assumption that $\zeta = 0$, public capital is a pure public good. When $\zeta = 0$, there are constant returns to scale to private inputs but increasing returns to scale to all inputs, though as we assume $\phi + (1 - \beta) < 1$, endogenous growth through capital accumulation is ruled out. $\zeta = 0$ is a polar case—in reality, almost all public goods are characterized by some degree of congestion.

The *efficiency/quality* of public capital ($\theta \in [0,1]$)

$\theta_t \in [0, 1]$, reflecting the fact that "a dollar's worth of public investment spending often does not create a dollar's worth of public capital" (Pritchett 1996)—K_t^{Gm} units of public capital act like $G_t = \theta_t K_t^{Gm}$ units, and it is only the latter that is useful for increasing output. That is, productive capital is sometimes not created at all; or supposedly productive capital is created but subject to implementation weaknesses and/or operational inefficiencies such that the cost is higher than the minimum required to build the capital.

More concretely, a low θ most closely resembles poor construction quality which impedes efficient operation of the public capital project. A good example of low quality/efficiency is a corrupt road construction project where the construction firm reduces the thickness of pavement to save money (and pays kickbacks to politicians/bureaucrats). The road surface then deteriorates much more quickly than it should if it were properly constructed, resulting in reduced travel speeds and capacity. This example closely relates to how we measure θ in practice based on the fraction of unpaved roads (or electricity/water transmission losses).

If θ mostly reflects construction quality, readers might wonder about other aspects of the public investment management process, such as poor project selection, excessive public investment in politically sensitive regions, or large vanity projects with little economic value. Unfortunately, it is close to impossible to assess the scale of these problems quantitatively across countries, and so they are excluded from our Infrastructure Efficiency Index (IEI) (and from θ), which is discussed in section 4. To the extent that vanity projects are a different class of public investment (even less essential than other public buildings), it could be argued that they are less *useful* for producing output and hence have a lower ϕ. But we would generally prefer adjusting down θ—below that implied by the IEI—which allows for potential improvement in the efficiency/quality of public investment in the future (and is closer to Pritchett's original formulation).

The *usefulness* of public capital for production ($\phi \in [0,1]$)

The elasticity of output with respect to the public capital stock measures the *usefulness* of public capital for production, assuming that the project is of maximum quality/efficiency ($\theta = 1$). Essential infrastructure like roads, ports, power, and water tend to have a higher usefulness than less essential forms of public capital, like public buildings, even if these different types are constructed properly. The calibration of values for this parameter is discussed in section 5.2.

Population and labor force growth

Equation (3) can be translated into per worker terms by dividing both sides by L_t:

$$y_t \equiv \frac{Y_t}{L_t} = A\left[\theta_t \left(L_t\right)^{1-\zeta} k_t^{Gm}\right]^{\phi} (k_t^P)^{1-\beta-\zeta\phi} h_t^{\beta} \qquad (4)$$

where y_t is output per worker and k_t^P is private capital per worker and k_t^{Gm} is measured public capital per worker (note the lower case). $L_t = \varrho_t \omega_t N_t$, where N_t is total population, ω_t is the working-age-population ratio and ϱ_t is the labor participation rate (labor force-to-working age population ratio). The above equation can then be used to calculate growth rates of output per worker from t to $t + 1$:

$$\frac{y_{t+1}}{y_t}=\left[\frac{\omega_{t+1}}{\omega_t}\frac{\varrho_{t+1}}{\varrho_t}\frac{N_{t+1}}{N_t}\right]^{(1-\zeta)\phi}\left[\frac{A_{t+1}}{A_t}\right]\left[\frac{\theta_{t+1}}{\theta_t}\right]^{\phi}\left[\frac{k^{Gm}_{t+1}}{k^{Gm}_t}\right]^{\phi}\left[\frac{k^{P}_{t+1}}{k^{P}_t}\right]^{1-\beta-\zeta\phi}\left[\frac{h_{t+1}}{h_t}\right]^{\beta} \tag{5}$$

Equation (5) can be rewritten in terms of growth rates from t to $t + 1$:

$$1+g_{y,t+1}=\left[\left(1+\Gamma_{t+1}\right)^{(1-\zeta)\phi}\right]\left(1+g_{A,t+1}\right)\left(1+g_{\theta,\,t+1}\right)^{\phi}\left(1+g_{k^{Gm},t+1}\right)^{\phi}\left(1+g_{k^{P},t+1}\right)^{1-\beta-\zeta\phi}\left(1+g_{h,t+1}\right)^{\beta} \tag{6}$$

where the growth rate of a variable x from t to $t + 1$ is denoted by $g_{x,t+1}$, and Γ is the growth rate of the number of workers:

$$1 + \Gamma_{t+1} = (1 + g_{\varrho,t+1})(1 + g_{\omega,t+1})(1 + g_{N,t+1}) \tag{7}$$

$1 + \Gamma_{t+1}$ drops out from equation (6) in the congestion default ($\zeta = 1$).

To obtain output per capita, y^{PC}_t from equation (4), $y^{PC}_t \equiv \frac{Y_t}{N_t}=\frac{Y_t}{L_t}\varrho_t\omega_t$. Rewriting this equation in terms of growth rates:

$$1+g^{PC}_{y,t+1}=\left(1+g_{y,t+1}\right)\left(1+g_{\varrho,t+1}\right)\left(1+g_{\omega,t+1}\right) \tag{8}$$

To obtain output growth, we multiply equation (8) with population growth:

$$1+g_{Y,t+1}=\left(1+g^{PC}_{y,t+1}\right)\left(1+g_{N,t+1}\right) \tag{9}$$

2.2 Public and private capital accumulation, and changes in the efficiency/quality of public capital

The *measured* quantity of public capital (as in international statistical databases) accumulates according to a standard capital accumulation identity, with the next period's stock coming from the previous period's undepreciated stock, $(1-\delta^G)K^{Gm}_t$ (where δ^G is the public capital depreciation rate) and new public investment, I^G_t.

$$K^{Gm}_{t+1}=\left(1-\delta^G\right)K^{Gm}_t+I^G_t \tag{10}$$

The gross growth rate of measured public capital (not per worker) is:

$$K^{Gm}_{t+1}/K^{Gm}_t=\left(1-\delta^G\right)+\frac{I^G_t/Y_t}{K^{Gm}_t/Y_t} \tag{11}$$

The growth rate of measured public capital *per worker,* which enters equation (6), is:

$$1+g_{k^{Gm},t+1}\equiv\frac{K^{Gm}_{t+1}}{K^{Gm}_t}/\frac{L_{t+1}}{L_t}=\frac{\left(1-\delta^G\right)+\frac{I^G_t/Y_t}{K^{Gm}_t/Y_t}}{\left(1+g_{\varrho,t+1}\right)\left(1+g_{\omega,t+1}\right)\left(1+g_{N,t+1}\right)} \tag{12}$$

The stock of efficiency-adjusted public capital (which is actually used in production) evolves based on the previous period's efficiency-adjusted undepreciated stock and efficiency-adjusted new investment $\theta^N_t I^G_t$.

$$G_{t+1}=\left(1-\delta^G\right)G_t+\theta^N_t I^G_t \tag{13A}$$

Readers will note that equation (13A) is the same as equation (1) in Berg et al. (2015), with the efficiency of new investment being θ^N_t rather than ε. Consequently, all of Berg et al.'s results on the effects of efficiency also go through here (discussed further below). Equation (13A) is also equivalent to equation (2) in Pritchett (2000), who refers to γ as the efficiency of public investment.[11] Here one can interpret $1/\theta_t^N$ as the dollar cost of providing an extra dollar of usable public capital. Hence, corruption or other rent seeking, which reduces the quality of public investment, effectively increases the cost of a given increase in the productive capital stock as found empirically by Olken (2007) and Collier, Kichberger, and Soderbom (2015).

θ_t is the average efficiency of existing public capital (rather than the efficiency of new investment). Substituting $G_t = \theta_t K_t^{Gm}$ into Equation 13A and rearranging as 13B, one can see the θ_{t+1} evolves as a weighted average of the quality of existing public capital θ_t, and the quality of new investment θ_t^N.

$$\theta_{t+1} = \theta_t \frac{\left(1-\delta^G\right)K_t^{Gm}}{\left(1-\delta^G\right)K_t^{Gm} + I_t^G} + \theta_t^N \frac{I_t^G}{\left(1-\delta^G\right)K_t^{Gm} + I_t^G} \tag{13B}$$

As such, the quality/efficiency of the stock of public capital only changes when the quality of new investment projects is different from that of the existing public capital stock: $\theta_t^N \neq \theta_t$.[12] Using equation (13B), the growth in quality which enters equation (6) can be written as follows:

$$1 + g_{\theta,\, t+1} \equiv \frac{\theta_{t+1}}{\theta_t} = \left[\left(1-\delta^G\right) + \frac{\theta_t^N}{\theta_t}\frac{I_t^G/Y_t}{K_t^{Gm}/Y_t}\right] / \left(K_{t+1}^{Gm}/K_t^{Gm}\right) \tag{14}$$

The quantity of private capital follows the same accumulation process as public capital. But with δ^P as the private capital depreciation rate, and I_t^P as private investment. The growth rate of private capital per worker is as follows:

$$1 + g_{k^P,t+1} = \frac{\left(1-\delta^P\right) + \dfrac{I_t^P/Y_t}{K_t^P/Y_t}}{\left(1+g_{\varrho,t+1}\right)\left(1+g_{\omega,t+1}\right)\left(1+g_{N,t+1}\right)} \tag{15}$$

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[11] The measured public capital stock K_t^{Gm} here is G_t^m in Berg et al. (2015). Pritchett (2000) refers to K_t^G in his equation (2) as the efficient capital stock.

[12] The treatment of "new" investment versus maintenance expenditure requires some clarification. For instance, Buffie et al. (2012), in their macroeconomic model of public investment effects, consider infrastructure investment as encompassing net investment, as well as operations and maintenance; and treat the depreciation rate as exogenous. Kalaitzidakis and Kalyvitis (2004), in their infrastructure-led growth model, specify the accumulation of public capital as a function of new investment, and the depreciation rate depends on maintenance expenditure. Our model is more in line with Buffie et al. (2012), in that depreciation is exogenous. Conceptually, I_t^G in our model could include spending on major repairs, which along with new investment helps offset the capital decumulation effects of depreciation. But practically, we note that maintenance spending is typically subsumed under public consumption data and hence is hard to gauge. (From a national accounts perspective, the SNA (1993) notes "ordinary maintenance and repairs to keep fixed assets in good working order are intermediate consumption. However, major improvements, additions or extensions to fixed assets which improve their performance, increase their capacity or prolong their expected working lives count as gross fixed capital formation. In practice, it is not easy to draw the line. . . . Some analysts . . . would favor a more "gross" method . . . all such activities are treated as gross fixed capital formation.") User concern about insufficient maintenance spending could thus be reflected as higher depreciation rates. Developing countries tend to spend less on operations and maintenance, which could imply higher depreciation rates than developed countries. (Devarajan, Swaroop, and Zou (1996), in a regression analysis for a sample of developing countries, find public capital expenditure and economic growth to be negatively correlated but that current expenditure has positive effects, illustrating how capital expenditure may have been excessive, while current expenditure insufficient). However, developed countries are more likely to hold a higher share of more sophisticated assets that are subject to faster depreciation, making the net implication for depreciation rates not readily obvious (Arslanalp et al. 2010).

2.3 Analysis of the drivers of growth

To better understand and simplify the analysis of the drivers of growth, we take a log-linear approximation of equation (6). Specifically, equations (12), (14) and (15) are substituted into equation (6). Then, taking logs and using the approximation $\ln(1+g) \approx g$ (for small g) we arrive at the following:

$$g^{PC}_{y,t+1} \approx g_{A,t+1} + \beta\left(g_{\varrho,\,t+1} + g_{\omega,\,t+1} + g_{h,t+1}\right) - (1-\beta)(g_{N,t+1}) + \phi\left[\theta^N_t \frac{I^G_t / Y_t}{\theta_t K^{Gm}_t / Y_t} - \delta^G\right] + (1-\beta-\zeta\phi)\left(\frac{I^P_t / Y_t}{K^P_t / Y_t} - \delta^P\right) \quad (16)$$

From equation (16), one can see that a 1ppt increase in the public investment share of GDP increases growth the following year by:

$$\frac{\partial g^{PC}_{y,t+1}}{\partial I^G_t / Y_t} = \frac{\phi}{\theta_t K^{Gm}_t / Y_t}\theta^N_t. \quad (16A)$$

$\frac{\phi}{\theta_t K^{Gm}_t / Y_t}$ is the marginal product of efficient public capital (G_t), calculated by taking the derivative with respect to $G_t = \theta_t K^{Gm}_t$. This is multiplied by θ^N_t, such that an increase in public investment has a larger effect on growth when new public investment is more efficient.

However, in most cases it is prudent to assume that the efficiency of new investment is the same as past investment, $\theta^N_t = \theta_t$. In this case, the effect of a 1ppt GDP increase in public investment is the marginal product of *measured* public capital, $\phi/(K^{Gm}_t / Y_t)$. To calculate how many extra ppts of GDP of public investment an economy needs in order to increase growth by a percentage point, simply invert this ratio $(K^{Gm}_t / Y_t)/\phi$. We call this the public marginal Incremental Capital to Output Ratio (ICOR), because it is a close analog of the traditional concept of ICOR.

An analogous expression is available for private capital:

$$\frac{\partial g^{PC}_{y,t+1}}{\partial I^P_t / Y_t} = \frac{1-\beta-\zeta\phi}{K^P_t / Y_t} \quad (16B)$$

The public capital portion of equation (16) in brackets is equal to the net growth rate of efficient public capital G_t. This can be further decomposed into an increase in quality $\left[\frac{\theta^N_t - \theta_t}{\theta_t}\right]\frac{I^G_t / Y_t}{K^{Gm}_t / Y_t}$ and an increase in quantity $\frac{I^G_t / Y_t}{K^{Gm}_t / Y_t} - \delta^G$. The increase in quantity is simply the net growth rate of the measured public capital stock $g_{K_{Gm}} = K^{Gm}_{t+1} / K^{Gm}_t - 1$ (which is not affected by the level of θ).

$$g_{G_t} = \left[\frac{\theta^N_t}{\theta_t}\frac{I^G_t / Y_t}{K^{Gm}_t / Y_t} - \delta^G\right] = \underbrace{\left[\frac{\theta^N_t - \theta_t}{\theta_t}\right]\frac{I^G_t / Y_t}{K^{Gm}_t / Y_t}}_{\textit{Quality increase}} + \underbrace{\frac{I^G_t / Y_t}{K^{Gm}_t / Y_t} - \delta^G}_{\textit{Quantity increase } (= g_{K_{Gm}})} \quad (17)$$

One will note that if $\theta^N_t = \theta_t$—that is the efficiency of public capital is constant—then the level of public capital efficiency θ_t does not appear at all in equations (16A), (16B), or (17) and so does not affect growth. This surprising result, which also appears in Berg et al. (2015), is because of two exactly offsetting forces in the production function. First, lower quality/efficiency naturally means that there is a smaller increase in efficient public capital for each extra 1ppt of public investment. Second, in economies with lower efficiency, the stock of efficient public capital is scarcer, and hence has a higher marginal product.[13]

From equation (16), TFP growth $g_{A,t+1}$ has the largest direct effect on growth. The effect of most other factors depends on the labor share, $\beta < 1$. The larger is β, the lower is the effect of private capital accumulation on growth. For both public and private capital accumulation, holding all else constant, the same level of investment-to-output becomes less efficient as the capital-to-output ratio rises.

3. Implementing public capital in the Long Term Growth Model (LTGM-PC)

	Submodel 1	Submodel 2	Submodel 3
Public investment/GDP	**Input**	Output	**Input**
Private investment/GDP	**Input**	**Input**	Output
growth target	Output	**Input**	Output
National savings/GDP	Output	Output	**Input**

In practical terms, using the LTGM-PC involves choosing the path for several inputs in the future (exogenous variables), and then the LTGM-PC calculates the future implied path of the outputs (endogenous variables). The LTGM-PC has three submodels (1–3) where the endogenous and exogenous variables in the model are switched. Other growth drivers—growth in TFP (A), human capital (h), labor participation rate (ϱ), working age-population ratio (ω), and population (N) respectively are always exogenous, as in the Standard LTGM. The LTGM-PC also allows for output growth to affect poverty rates, as in the Standard LTGM. More technically, the LTGM-PC has three "state" variables, which are predetermined at any point and change slowly over time: the public and private capital stocks (usually expressed as a ratio to GDP) and the average efficiency of installed public capital.

In this chapter, we mostly use **Submodel 1** where future paths of public and private investment (as a share of GDP) are exogenous, and the path of GDP (or GDP per capita) is endogenous. Alternatively, this can be reversed and **Submodel 2** can calculate the required public investment ratio to achieve a specified growth target (given an exogenous private investment share). In both submodels 1 and 2, savings rates are calculated as a residual for an assumed path of the current account balance to GDP ratio. In **Submodel 3**, the user instead specifies national savings rates and public investment rates as exogenous, with the model calculating implied private investment and growth rates.

3.1 Submodel 1: Growth given public and private investment

In Submodel 1, per capita output growth ($g_{y^{pc},t+1}$) is generated by equation (8), based on growth in GDP per worker growth ($g_{y,t+1}$) from equation (6). The components of equation (6) are:

[13] Countries with different efficiency levels will have the same marginal product of public investment given the same parameters and initial conditions. The marginal product of public investment depends on the marginal product of efficient public capital and the translation of public investment to efficient capital and can be expressed as follows (using Equation (3) and (13)):

$$\partial Y_{t+1} / \partial I_t^G = \left(\partial Y_{t+1} / \partial \theta_{t+1} K_{t+1}^{Gm}\right)\left(\partial \theta_{t+1} K_{t+1}^{Gm} / \partial I_t^G\right) = (\phi Y_{t+1} / \theta_{t+1} K_{t+1}^{Gm})\theta_t^N$$

Note that θ_{t+1} and θ_t^N cancel out if efficiency is unchanged.

- The future growth rates of the labor participation rate ($g_{\varrho,t+1}$), the working age-population ratio ($g_{\omega,t+1}$), population ($g_{N,t+1}$), human capital ($g_{h,t+1}$), and pure TFP ($g_{A,t+1}$), which are exogenous and can be determined by the user.
- The growth rate of measured public capital per worker ($g_{kGm,t+1}$), which is given by equation (12), using the growth rate of the public capital stock (equation (11)) as an intermediate step.
- Private capital per worker growth ($g_{k^P,t+1}$) as given by equation (15).
- The growth rate of the efficiency of public capital ($g_{\theta,t+1}$) as given by equation (14) using the growth rate of the public capital stock (equation (11)) as an intermediate step.

Finally, the model is closed by updating public capital-to-output using equation (18) and the private capital-to-output ratio using equation (19) (with the growth rates in per-worker terms):

$$\frac{K_{t+1}^{Gm}}{Y_{t+1}} = \frac{K_t^G}{Y_t}\frac{\left(1+g_{k^{Gm},t+1}\right)}{1+g_{y,t+1}} \tag{18}$$

$$\frac{K_{t+1}^{P}}{Y_{t+1}} = \frac{K_t^P}{Y_t}\frac{\left(1+g_{k^{P},t+1}\right)}{1+g_{y,t+1}} \tag{19}$$

3.2 Submodel 2: Public investment required to generate a target growth rate (given a constant private investment rate)

Submodel 2 is particularly useful for assessing the feasibility of a public investment–led growth strategy. Specifically, one can ask what rates of *public* investment would be required to generate a given target growth rate, assuming a path for *private* investment. Across countries, public investment is typically around 6% of GDP, and more than 90% of countries have public investment rates less than 12% of GDP.[14] As such, if a growth strategy required an increase in public investment rates of more than a few percentage points of GDP, it should be regarded as ambitious, and in some cases unrealistic. In practice, the required rates of public investment using Submodel 2 are often extremely high or low if the target growth rate is not close to that achieved by the economy under business-as-usual public investment rates.

To find the required public investment share to achieve the target per capita growth rate:

- First, rearrange equation (8) to calculate required GDP growth per worker:

$$1+g_{y,t+1} = \frac{1+g_{y,t+1}^{PC}}{\left(1+g_{\varrho,t+1}\right)\left(1+g_{\omega,t+1}\right)} \tag{20}$$

- Then rearrange equation (6) to calculate the combined growth rate of efficiency-adjusted public capital per worker ($\theta_t K_t^{Gm}/L_t$) required to generate the target growth in GDP per worker in equation (20). Note here that $g_{A,t+1}$, $g_{h,t+1}$, and Γ_{t+1} are all always exogenous, and the growth rate of private capital per worker $g_{k^P,t+1}$ is calculated using equation (15) (as the private investment share is exogenous in Submodel 2).

$$\left(1+g_{\theta,t+1}\right)\left(1+g_{k^{Gm},t+1}\right) = \frac{\theta_{t+1}K_{t+1}^{Gm}/L_{t+1}}{\theta_t K_t^{Gm}/L_t} = \left[\frac{1+g_{y,t+1}}{\left(1+g_{A,t+1}\right)[(1+\Gamma_{t+1})^{(1-\zeta)\phi}]\left(1+g_{k^P,t+1}\right)^{1-\beta-\zeta\phi}\left(1+g_{h,t+1}\right)^{\beta}}\right]^{1/\phi} \tag{21}$$

[14] Figures for 2016, with the investment share of GDP from the World Bank MFMOD database on the public investment share from the IMF FAD databases. Cross-country mean is 6.47% and cross-country median is 5.4% of GDP.

- Finally, one can rearrange equation (13A) in per worker terms to solve for the investment share of GDP (recall that Γ is the growth rate of the number of workers, as in equation (7)):

$$I_t^G / Y_t = [\left(1+g_{\theta,t+1}\right)\left(1+g_{k^{Gm},t+1}\right)\left(1+\Gamma_{t+1}\right)-(1-\delta^G)]\frac{K_t^{Gm}/Y_t}{\theta_t^N/\theta_t} \tag{22}$$

- As before, one also needs to update the state variables $(\theta_t, K_t^{Gm}, K_t^P)$. Equation (14) updates the efficiency of public capital for *t+1,* and equation (19) updates the private capital-to-output ratio. Equations (11) and (12) calculate the growth rate in the public capital stock (per worker) implied by the rate of public investment and equation (18) updates the new public capital-to-output ratio.

3.3 Submodel 3: Growth given savings and public investment rates

Any growth strategy involving an increase in public investment rates needs to take account of the fact that greater public investment needs to be funded by either domestic or foreign savings. In the absence of policies to increase national savings (or increase access to foreign savings), an increase in public investment will crowd out private investment, resulting in a smaller increase in growth than would otherwise be the case if there was no savings constraint. This mechanism is captured in Submodel 3, where the user specifies the national savings rate as well as a path for public investment.

- Private investment is then calculated by:
  - equation (23) if the user chooses to specify the current account balance,

$$\frac{I_t^P}{Y_t}=\frac{S_t}{Y_t}-\frac{CAB_t}{Y_t}-\frac{I_t^G}{Y_t} \tag{23}$$

  - or equation (24) if instead they specify a path for external debt as a share of GDP (see the description of the Standard LTGM for a derivation of these equations).[15]

$$\frac{I_t^P}{Y_t}=\frac{S_t}{Y_t}+\frac{FDI_t}{Y_t}+\frac{D_t}{Y_t}-\frac{D_{t-1}/Y_{t-1}}{\left(1+g_{y,t}^{PC}\right)\left(1+g_{N,t}\right)}-\frac{I_t^G}{Y_t} \tag{24}$$

  Where CAB_t is the current account balance, FDI_t is inbound foreign direct investment, and D_t is end-of-year external debt.
- Once private investment is determined, the rest of the equations are the same as in Submodel 1.

4. Evidence on the efficiency/quality of the public capital stock, θ

This section develops a new Infrastructure Efficiency Index (IEI) to measure the proportion of public capital spending that delivers useful public capital/infrastructure services. For example, power lines and power plants might not deliver electricity to households and businesses, dams and pipelines might not be able to deliver water due to leaks, and roads may be in poor condition (such as being unpaved) (World Bank 1994). The IEI combines these measures into a single index for all countries.

[15] Strictly speaking, in the LTGM, external debt, *D,* can capture all foreign portfolio assets and liabilities, which means *D* could be decreasing if the country is accumulating foreign assets, for example through a sovereign wealth fund.

4.1 A new Infrastructure Efficiency Index

An infrastructure efficiency index (IEI) for measuring θ_t in the model above should have several key features: (i) informative about many countries; (ii) simple and transparent in its construction; and (iii) cardinal rather than conveying a relative rank/score. A cardinal index is needed because a doubling of θ_t in our model *doubles* the efficient public infrastructure stock, whereas a doubling in score or rank could mean the increase in the efficient public infrastructure stock is smaller or greater than double. While there are other infrastructure efficiency indices in the literature (surveyed below in section 4.2), none of them have all three features. Our new IEI does, following a similar methodology as Rioja (2003),[16] but for as many countries as possible subject to data availability.

Specifically, we construct the index using more recent data for three indicators: (i) electricity transmission and distribution losses (% of output); (ii) water losses (% of provision); and (iii) paved roads (% of total roads). Ideally, we would like to have used the percentage of paved roads in good condition as a subcomponent of the IEI. However, this statistic is no longer available. As such, we follow Calderon and Serven (2010) who use paved roads (% of total roads) as an indicator of the quality of road networks in their analysis of the quantity and quality of infrastructure services in Latin America. We nevertheless recognize that unpaved roads are not always undesirable or inefficient and may depend on country-specific geographic features. Electricity losses reflect inefficiency at the transmission and distribution stages—which is what our index intends to measure—but also electricity delivered but not paid for which can be attributable to theft and unmetered supply. For some countries the second type of non-technical losses can be large—however, this can still to some extent be seen as related to dysfunctional infrastructure in terms of construction and management (or operational inefficiency) (Jimenez, Serebrisky, and Mercado 2014). We also do not include telecommunications in the composite index since fixed-telephone line faults may no longer be relevant due to the rising importance of mobile telephony, and data on the quality of mobile phone service are not as extensive.

In calculating the IEI, we want to include the latest data, but also recognize that infrastructure losses for a single year can be very noisy. As such we take the average of the index for the latest available year and the post 2000 average, using a weighted average of water losses, power losses, and paved roads:

Individual country $IEI = \frac{1}{2}\left(\sum_{n=1}^{3} w_n I_{n,avg(2000-latest)} + \sum_{n=1}^{3} w_n I_{n,latest\ \ available\ \ value\ \ (starting\ \ 2000)}\right)$

where:

- I_n equals the portion of efficient infrastructure type, *n,* calculated as 100 – electricity transmission and distribution losses (% of output), 100 – water losses (% of provision), and paved roads (% of roads) respectively;
- *avg* (2000 - *latest*): the average of available values of the infrastructure indicator, *n,* from 2000 until the latest data point;
- *latest available value* (*Starting* 2000): the latest value available, the cut-off being the year 2000 (a country is excluded if its latest data point is before 2000); and
- w_n = infrastructure stock weight associated with each infrastructure, *n.* The weights are based on Fay and Yepes (2003) and vary with income groups but not over time (see table 2.1).

[16] Rioja (2003) uses the physical infrastructure losses reported in World Bank (1994), weighted by corresponding infrastructure stock shares according to Ingram and Fay (1994), to proxy the efficiency parameter for public capital stock in seven Latin American countries and five industrialized countries. The infrastructure loss indicators comprise electricity power transmission and distribution losses (% of output), faults per 100 main telephone lines per year, percentage of paved roads not in good condition, and water losses (% of total provision). Calderon and Serven (2004, 2010) construct an infrastructure quality index based on the first principal component of electricity losses, the share of paved roads, and the waiting time for telephone line installation.

Table 2.1: The Composition of Infrastructure Stocks (Fay and Yepes 2003)

	Low income	Middle income	High income
		%	
Electricity	28.13	55.87	44.70
Water	15.93	11.50	5.24
Roads	55.93	32.64	50.06
Total	100.00	100.00	100.00

Weights have been normalized, based on initial weights from Fay and Yepes (2003), table 2 (page 2), which also include rail and telecommunications. The weights calculated by Fay and Yepes are for the year 2000 and are based on estimations of the monetary value of infrastructure stocks, using best practice prices (unit costs).
Source: Fay and Yepes (2003)

Figure 2.1: Infrastructure Efficiency Index (IEI)—Correlation with Per Capita Income and Infrastructure Quality Score

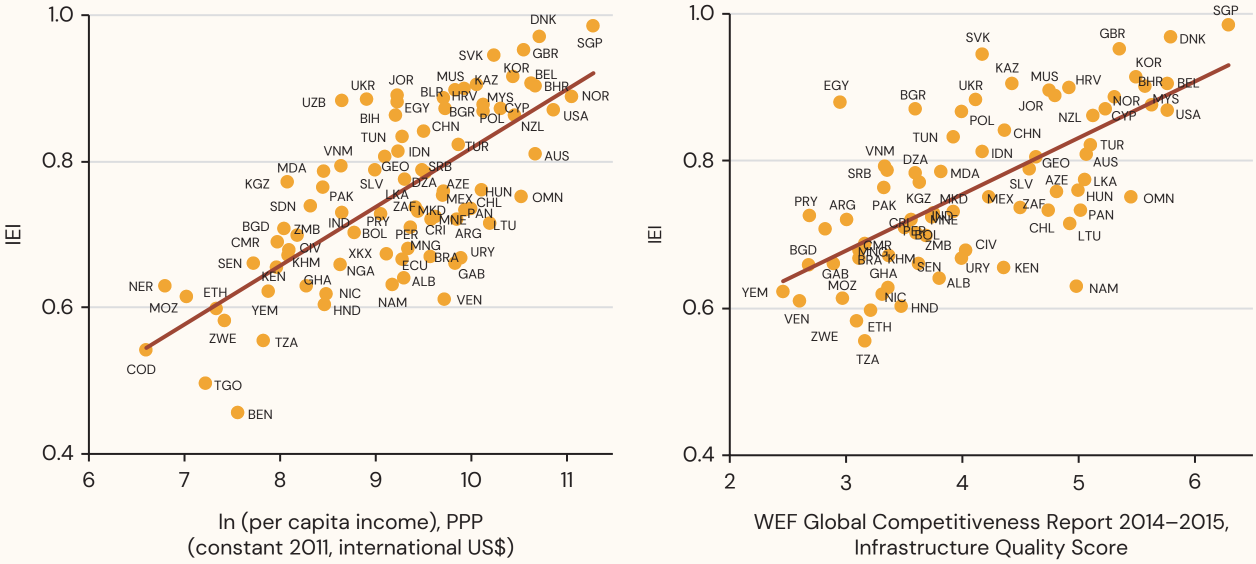


Figure 2.1 shows that the IEI has the expected properties, rising with GDP per capita (correlation: 0.72); and the World Economic Forum (WEF) Global Competitiveness Report's survey-based infrastructure quality indicator (correlation: 0.68). According to the IEI, efficiency is highest in high-income countries (including OECD members), with an average of 84%, followed by middle-income countries (77% for upper-middle-income countries and 74% for lower-middle-income countries), and low-income countries (58%). Further details on the sources of data and IEI summary statistics, as well as discussion on robustness checks for the index are provided in appendix 2.

4.2 IEI versus other measures of public investment efficiency

In this section, we briefly discuss some of the other measures of public investment efficiency that are available. These serve as useful checks against the IEI, but also face some limitations for use in our model—primarily that they indicate relative performance rather than being a cardinal measure.

Afonso, Schuknecht, and Tanzi (2005, 2010) and various IMF papers, starting with Albino-War et al. (2014) take the approach of distance to frontier, where inefficiency is measured relative to best performing peer countries. In the case of the papers by Afonso, Schuknecht, and Tanzi (2005, 2010) which respectively cover 23 industrial countries (2005 paper), and 23 emerging and new EU member states (2010 paper), the output measure is a composite of public sector performance based on a series of quantitative and qualitative socioeconomic indicators, while the input measure is public sector spending (i.e., more than just public investment).[17] For our model analysis purposes, we find that the results from these two papers may not be suitable because (i) the outcome variable encompasses broad, indirect macroeconomic outcomes; and (ii) efficiency is compared within a small group of countries—this may be particularly worrisome in the case of the emerging market/new EU member sample.[18]

On the other hand, the IMF public investment efficiency indicator (PIE-X) covers more than 100 countries. The output variables are directly related to infrastructure—a quantity index (physical infrastructure coverage and provision of social services[19]) and a survey-based quality index[20] respectively, as well as a hybrid of the two; while the input variable is public capital stock per capita.[21] While individual country efficiency scores have not been published, group averages of the quantity indicator suggest that advanced economies are 70% efficient (infrastructure output could be increased by 30% for the same amount of public capital input), emerging markets are 60% efficient, while low-income developing countries are at about 45% efficiency. Nevertheless, these are still *relative* performance indicators rather than cardinal indicators of quality: a score of 70% does not mean that 30% of infrastructure stock is not productive but rather the economy is operating 30% below the best performer in its peer group.

Aside from the above measures of inefficiency, there is also the IMF Public Investment Management Index (PIMI) (see Dabla-Norris et al. 2012), a purely qualitative indicator based on scores for individual country performance in terms of the investment process (project appraisal, selection, implementation, and evaluation). While it provides information on relative performance across 71 developing countries and shows a positive correlation with GDP per capita and indicators of governance quality, it is not a cardinal indicator of the proportion of public capital that is productive, and only measures the quality of input process. Despite this, Gupta et al. (2014) normalize the index on a 0–1 scale and use it as a measure of efficiency-adjusted public capital effects on growth based on a sample of 52 countries. They find that upper-middle-income countries have on average 57% efficient public capital stock against 46% for lower-middle-income countries, and 38% for low-income countries.[22]

Table 2.2 summarizes the PIE-X and PIMI and how they compare against the IEI. While caution should be exercised in comparing outcomes in absolute terms across different methodologies, one crucial takeaway is that all methodologies point to a gap between high-income countries and low-income countries. Thus, there appears to be substantial room for improvement in efficiency in low-income countries, which could lead to a better growth performance.

[17] Qualitative indicators of corruption, red tape, judiciary efficiency, public infrastructure quality; and quantitative indicators of shadow economy size, secondary school enrollment, education achievement, infant mortality, and life expectancy; as well as broad macroeconomic outcomes of income distribution, growth performance and stability, inflation, and unemployment.

[18] Sinha (2017) uses the emerging market/new EU member state average efficiency as a reference point for public investment efficiency in Bangladesh.

[19] Length of road network, electricity production, access to water, number of secondary teachers, and number of hospital beds.

[20] Based on the World Economic Forum Global Competitiveness Report survey responses on the quality of key infrastructure services.

[21] With GDP per capita as an auxiliary input variable.

[22] We group Gupta et al. (2014)'s individual country calculations according to the World Bank income classification scheme.

Table 2.2: **Indicators of Efficient Public Capital Stock – Different Methodologies**

Infrastructure Efficiency Index (IEI) (this chapter)		Public Investment Efficiency Indicator (PIE-X)				Efficiency-adjusted public capital, using Public Investment Management Index (PIMI)	
	Average		Hybrid, average	Physical, average	Survey-based, average		Average
High-income (21)	0.844	All countries (132)	0.730	0.570	0.800	Upper-middle-income (14)	0.572
Upper-middle-income (25)	0.767	Advanced (26)	0.870	0.700	0.900	Lower-middle-income (22)	0.456
Lower-middle-income (27)	0.738	Emerging markets (62)	0.730	0.600	0.800	Low-income (14)	0.382
Low-income (10)	0.576	Low-income developing countries (44)	0.600	0.450	0.750		

Note: Mean of simple and weighted average of output not lost in delivery (for electricity and water) and paved roads as percentage of total roads.

Note: Based on efficiency frontier analysis with public capital stock per capita as input and infrastructure quantity and/or quality as output. The hybrid indicator is a simple mean of the physical and survey-based indicators.
Source: IMF (2015).

Note: The capital accumulation process is based on efficient public investment. The portion of public investment deemed as efficient is based on a time-invariant PIMI score (between 1 and 4) that has been normalized (4 to 1).
Source: Gupta et al. (2014).

5. Model calibration

5.1 Setting up the baseline and scenarios

To make empirical comparisons *between* the Standard LTGM and the public capital extension (LTGM-PC), as well as *within* the public capital extension (public versus private investment, increasing quantity versus quality of public investment), we run simulations using both models for a sample of 147 countries. To solve each model, we need to first input baseline parameters, initial conditions and paths of variables for individual countries. Data sources and calculations are detailed in table 2.3.

5.2 Calibration of select parameters

5.2.1 The usefulness of public capital ϕ (elasticity of output with respect to public capital)

The effect of public investment on growth is most sensitive to the elasticity of output to public capital, ϕ, which we calibrate carefully in this subsection based on two meta-analysis studies— Bom and Ligthart (2014) and Nunez-Serrano and Velazquez (2016)—and a recent paper by Calderon, Moral-Benito, and Serven (2015). Meta-analyses are necessary due to the controversy in the literature on this parameter with a range of studies with different samples, definitions, and methodologies. Our default value is $\phi = 0.17$, which is the upper bound across the two meta-analyses and should be applied to "essential infrastructure" or "productive capital" only and is the same as in the IMF's DIG model (Buffie et al. 2012). As such, our default calibration should be viewed as being relatively optimistic about the growth effects of public capital. An alternative value (which could be viewed as a lower bound) is $\phi = 0.10$ for

Table 2.3: Baseline Parameters, Initial Conditions, and Paths of Variables

Constant parameters	**Model(s)**	**Source/calculation**
Labor share β	Std LTGM LTGM-PC	Latest individual country β, based on Penn World Tables (PWT) version 8.1, or the Global Trade Analysis Project (GTAP) database. Labor shares below 0.45 or above 0.70 were trimmed to those values to remove outliers.
Elasticity of output to public capital ϕ	LTGM-PC	0.170 (default) and 0.100 for all countries. See section 5.2 for discussion of this calibration.
Congestion ζ	LTGM-PC	1 (congestion) or 0 (pure public good) is assumed for all countries.
Efficient public capital stock θ	LTGM-PC	Infrastructure Efficiency Index (IEI)—ee section 4. Unchanged efficiency is assumed for all countries.
Aggregate depreciation rate δ	Std LTGM	Latest value from PWT 8.1.
Public capital and private capital depreciation rates δ^G, δ^P	LTGM-PC	δ^G = 2% for all countries, which is the average depreciation rate for structures in the PWT 8.1. δ^P, individual country-specific, is the residual from the weighted average calculation.
Initial Conditions		
Initial capital-to-output ratio $\frac{K_0}{Y_0}$	Std LTGM	Individual country values are based on the most recent data in PWT 8.1.— Capital stock at constant 2005 national prices (2005 US$ mil.)/ Real GDP at constant 2005 national prices (2005 US$ mil.). Capital-to-output ratio (K/Y) below 1.5 or above 3.5 were trimmed to those values to remove outliers.
Initial measured public capital-to-output and private capital-to-output ratios $\frac{K_0^{Gm}}{Y_0}, \frac{K_0^P}{Y_0}$	LTGM-PC	Individual country values are derived by applying 2015 shares of public and private capital calculated by the IMF Fiscal Affairs Dept. to PWT data on $\frac{K_0}{Y_0}$. IMF data: http://www.imf.org/external/np/fad/publicinvestment/.
Projected paths		
TFP growth g_A	Std LTGM LTGM-PC	Individual country average value over 2001–2010 based on PWT 8.1 (or applying PWT methodology with GTAP labor shares). Missing TFP in PWT calculated by Barrot (2016) using GTAP labor share. Negative TFP growth adjusted up to zero.
Human capital growth rate g_h	Std LTGM LTGM-PC	Individual country average value over 2001–2010 from PWT 8.1, based on years of schooling and returns to education.
Growth in labor participation rate g_ϱ	Std LTGM LTGM-PC	International Labor Organization (ILO) individual country data for 2014, available from the World Development Indicators (WDI) Database.
Population growth g_N	Std LTGM LTGM-PC	World Bank compilation of data sourced from the United Nations Population Division and country censuses. Projections for 2016 to 2050.
Growth in the working age-to-population rate g_ω	Std LTGM LTGM-PC	World Bank estimates based on United Nations Population Division data on age and sex distribution of population. Projections for 2016 to 2050.
Investment-to-output ratio $\frac{I}{Y}$.	Std LTGM	Individual country data are based on most recent data in WDI—(Gross fixed capital formation (constant 2010 US$)/GDP (constant 2010 US$).

(Continued)

Table 2.3: continued

Constant parameters	Model(s)	Source/calculation
Public investment-to-output and private investment-to-output ratios $\frac{I^G}{Y}, \frac{I^P}{Y}$.	LTGM-PC	Individual country values are derived by applying the 2015 shares of public and private investment calculated by the IMF FAD to WDI data on $\frac{I}{Y}$. IMF data: http://www.imf.org/external/np/fad/publicinvestment/.

The sample of countries is guided by the availability of human capital data. For missing data in other variables, these are interpolated for the affected countries based on the median value of available data for the corresponding country groups by income. An initial sample of 151 countries was reduced to 147 to exclude outliers that appeared in the top graphs of figure 2.2 (The Bahamas, Egypt, Iran, and Uzbekistan).

all public capital. This latter value is slightly larger than the estimates in Calderon, Moral-Benito, and Serven (2015) of $\phi = 0.07 - 0.10$.

Bom and Ligthart (2014) look at 68 empirical studies[23] which cover the period 1983–2008. These studies are based on the production function approach and measure public capital in monetary and stock terms. Bom and Ligthart's meta-analysis indicates an average elasticity of output to public capital of 0.106 (not reported), which is higher in the long run and for core public capital, but lower for the aggregate public capital/national government level (compared to the regional/local government level).

Nunez-Serrano and Velazquez (2016) consider 145 papers[24] which cover the period 1983–2011. The empirical studies scrutinized are predominantly those that take a production function approach (85% of the sample) and include studies that use nonmonetary (17%) and flow (7%) measures of public capital. They find an average elasticity of output to public capital of 0.132, which is higher in the long run, 0.161. Though with less statistical significance, there is also an indication that the elasticity value is higher with productive public capital. The distinction between monetary and nonmonetary measures of public capital does not have a discernible effect. A summary of select results from the respective meta-analyses of Bom and Ligthart (2014) and Nunez-Serrano and Velazquez (2016) is presented in table 2.4.

Neither of the two meta-analyses contains a discussion of potential differences in ϕ between developed and developing countries. However, Calderon, Moral-Benitok, and Serven (2015),[25] using a relatively extensive cross-country sample, find that the long-run elasticity of infrastructure does not seem to vary with countries' per capita income levels, infrastructure endowment, or population size.

5.2.2 Initial capital-to-output ratios and depreciation rates

Our default data source for aggregate data on capital stocks and depreciation rates is the Penn World Tables (PWT) 8.1, which is also used in the Standard LTGM. Unfortunately, PWT 8.1 does not include the split into public and private capital, so we rely on data from the IMF for the relative shares of public and private capital stocks (see IMF 2015 and http://www.imf.org/external/np/fad/publicinvestment/).[26]

[23] Of the 68 studies, 5 cover country groups (of which one is exclusively developing countries) and 63 are country-specific (all advanced economies).

[24] Of the 145 studies, 26 cover country groups (of which five are exclusively developing countries) and 119 are country-specific (of which five are developing countries).

[25] In the study, infrastructure is measured as a composite of several physical infrastructure indicators (as opposed to the monetary value of capital stock). A panel data set is used, comprising 88 countries that cut across different income levels and infrastructure endowments.

[26] We use the following data from the IMF to calculate the shares: general government capital stock and private capital stock in billions of constant 2011 international dollars.

Table 2.4: Elasticity of Output to Public Capital, ϕ ("usefulness")

Bom and Ligthart (2014):*	
Core infrastructure[a]	0.170
Total public capital	0.122
Nunez-Serrano and Velazquez (2016):*	
Productive capital[b]	0.175
Total public capital	0.161
Calderon, Moral-Benito, and Serven (2015) (infrastructure):*	0.07 to 0.10

[a] Refers to roads, railways, airports, and utilities.
[b] Refers to capital aimed at health, education, housing and community services, energy installations, and communication and transport infrastructure. Values are computed based on results reported in Table 3, Section B.a. of Nunez-Serrano and Velazquez (2016).
*Long-run estimates. Note that most studies control for the total or private capital stock.

Given different computation methodologies, aggregate K/Y ratios differ between the PWT 8.1 and the IMF, and are on average lower in the latter case.[27] We assume that public capital is mostly structures, and so apply the 2% structures depreciation rate from PWT 8.1. The private capital depreciation rate is a residual determined by the country-specific PWT 8.1 depreciation rate for aggregate K: $\delta = \delta^G \frac{K^{Gm}}{K} + \delta^P \frac{K^P}{K}$.

5.2.3 Congestion ($\zeta = 1$) versus pure public good ($\zeta = 0$) and actual versus measured TFP growth

Users of the LTGM-PC must choose either a calibration with congestion ($\zeta = 1$) or without it (pure public good $\zeta = 0$). Unless users strongly feel that public capital in their country is not congested, we recommend using the congestion calibration. We use this ourselves as the default for the results in this chapter and in the Excel-based tool. The reason is that without congestion, *actual* TFP in the model (A_t in equation 1) tends to depart from *measured* TFP using standard growth accounting exercises. In any practical application of the LTGM-PC, the actual TFP growth rate is one of the most important assumptions, and also the most difficult to calibrate. When using the congestion specification, the actual TFP growth rate is similar to what one would get applying a standard growth accounting exercise. In contrast, without congestion the measured TFP growth rate is above the actual TFP growth rate, and so cannot be used to guide the calibration of the actual TFP growth rates without some kind of adjustment.

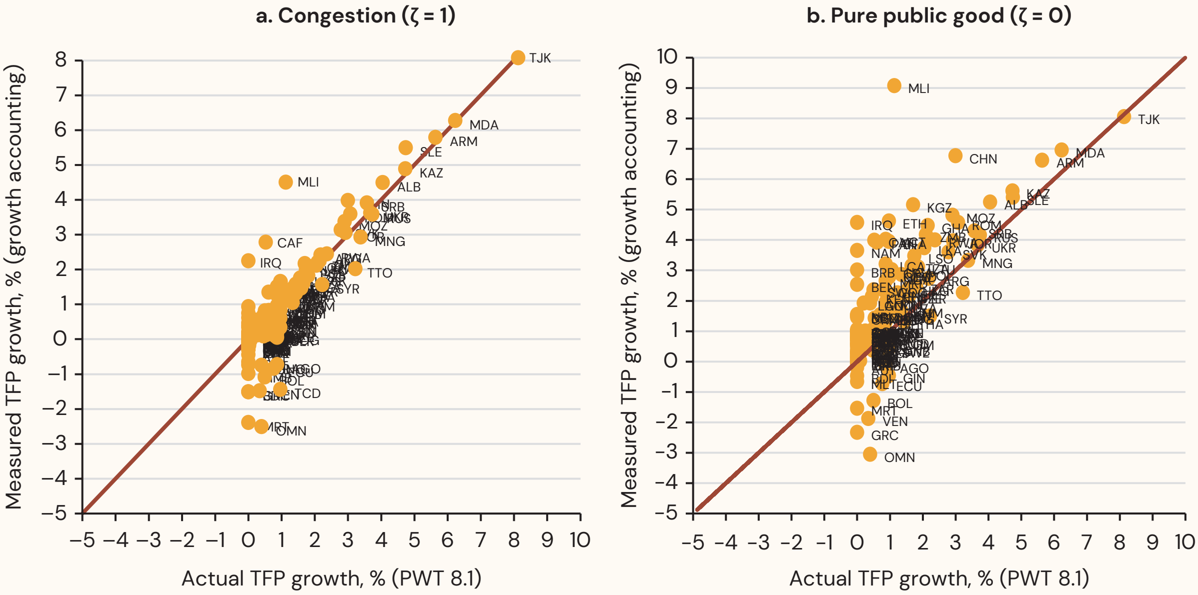
To see this, for each country we used the LTGM-PC to generate a growth path by assuming that actual TFP growth (A_t) was the same as that recorded in PWT 8.1 (over a 10-year average).[28] Then we performed a standard growth accounting exercise on the generated growth rates (given growth rates of other growth fundamentals, such as human capital and the total capital stock), to generate *measured* TFP growth. We then compared the measured TFP growth to the inputted actual TFP growth.

Figure 2.2 plots actual (x-axis) versus measured (y-axis) TFP growth for the congestion ($\zeta = 1$, LHS) and pure public good ($\zeta = 0$, RHS) calibrations. As one can see, generally actual and measured TFP growth are

[27] Both sources of data use variations of the perpetual inventory method to estimate aggregate capital stocks and do not take into account the destruction/damage of capital from wars/conflicts (which is naturally difficult to measure). Wars/conflicts also reduce output, perhaps faster than they destroy capital, and so the aggregate K/Y ratio may rise as a country enters a war/conflict. In the reconstruction period, it would not be surprising if measured public capital is extremely high because it fails to take account of the public capital destroyed in the conflict.

[28] To be clear, the exercise is not dependent on the source of assumed actual TFP growth, but just that its distribution across countries is reasonable.

Figure 2.2: Measured TFP Growth from LTGM-PC (ϕ = 0.17) Based on Growth Accounting versus Actual TFP Growth



Note: Excludes outliers, Liberia, and Macao, the former showing large negative measured TFP growth under congestion, and the latter large positive measured TFP growth in the pure public good setting.

See table 2.3 on the calculation of actual TFP growth. Measured TFP growth is obtained using traditional growth accounting (with total capital stock) based on the initial (2017) baseline output growth rates of the congestion and pure public good calibrations.

very similar (close to the 45-degree line) for the congestion specification, but less so for the pure public good specification. Quantitatively, the mean absolute deviation (MAD) between actual and measured TFP growth for congestion is around 0.6ppts, whereas for the pure public good specification it is twice as large (1.2ppts), and also measured TFP growth is biased upwards.[29]

This result can be shown analytically with some mild assumptions. Let measured TFP growth be $g_A^{meas} = g_Y - \beta(g_h + g_L) - (1-\beta)g_K$ (where g_k is the growth rate of the total capital stock), and actual TFP growth in the LTGM-PC (from equation (3), rearranged in growth rates) be $g_A^{actual} = g_Y - \beta(g_h + g_L) - \phi(g_\theta + g_{K^{Gm}}) - (1-\beta-\zeta\phi)g_{K^P}$. In order for standard growth accounting to inform our TFP growth assumptions, we need $g_A^{meas} = g_A^{actual}$ which implies $\phi(g_\theta + g_{K^{Gm}}) + (1-\beta-\zeta\phi)g_{K^P} = (1-\beta)g_K$. If we assume that (i) there is no trend growth in efficiency ($g_\theta = 0$, which must be true in the long run as θ is bounded above by 1), and (ii) all capital stocks grow at approximately the same nonzero rate ($g_K \approx g_{K^{Gm}} \approx g_{K^P} \neq 0$), then $g_A^{meas} = g_A^{actual} \Rightarrow \zeta = 1$.

A corollary is that if growth rates of the different types of capital are similar (and other fundamentals are the same), then the growth rate of GDP generated by the LTGM-PC is consistent with a growth rate generated by a canonical neoclassical model with aggregate capital like the Standard LTGM. We show this numerically in appendix A1.3.

[29] The MAD between actual and measured TFP growth when public capital was assumed to be less useful (ϕ = 0.1) was also smaller for the congestion specification (0.6ppts) than the pure public good specification (1.0ppts).

6. Results: Stylized facts and the effect of an increase in investment on growth

6.1 Stylized facts on the infrastructure gap and the return to public/private investment

It is often argued that there is a large public infrastructure gap in developing countries, with current public infrastructure falling far short of what is needed. From a human development perspective this is definitely true, based on figures like 700 million people without safe drinking water and 1.2 billion people without electricity (as quoted in the introduction). But does this public infrastructure gap mean that the return to new public investment in developing countries is much higher than that in developed countries? Put another way, are developing countries particularly short of public capital *relative to their level of development?* What about if we adjust for the lower quality of public capital in developing countries? And are they short of public infrastructure relative to, say, private capital?

In this section we answer these questions through the lens of our calibrated model for representative countries at various stages of development based on the World Bank classification:[30]

- Low-income (LI) - GNI PC < $1,000
- Lower-middle-income (LMI): $1,000 < GNI PC < $4,000
- Upper-middle-income (UMI): $4,000 < GNI PC < $12,000
- High-income (HI): GNI PC > $12,000.

Parameters for each "representative country" are the within-group medians (table 2.5)[31], taken from an overall sample of 108 countries with complete (non-interpolated) data. A caveat here is that the sample of LI countries with complete data is quite small (only 12 countries), and so there is a chance that results for that group might change with better data. We report results using the default congestion setting ($\zeta = 1$) for essential infrastructure ($\phi = 0.17$)—with robustness to other parameters reported in appendix 3. In addition to answering the questions above, this also provides a guide to how the LTGM-PC might be used in specific countries.

We find no evidence that *measured* public capital is particularly scarce for LI or LMI countries relative to GDP. In fact, public capital as a share of output is relatively constant across various levels of development at around $K^{Gm}/Y = 0.92$ (± 0.05), with LI countries having the highest K^{Gm}/Y and LMI countries being in the middle of the group (table 2.5,panel A). If anything, it is HI countries that are relatively short of public capital, as their ratio of $K^{Gm}/Y = 0.86$ is the lowest.

How do we square this with the narrative of infrastructure gaps above? The first answer is that developing countries are short of productive public capital (G_t/Y_t), rather than measured public capital (K_t^{Gm}/Y_t) – an issue we revisit in Section 6.4. As argued in Keefer and Knack (2007), developing countries with poor institutions tend to have higher rates of public investment, which the authors argue are inflated to provide rents and kickbacks.

[30] Cutoffs are expressed in GNI per capita (to 2 significant figures), calculated using the World Bank Atlas method.

[31] Replication files for the main tables and figures are available from the authors upon request.

Table 2.5: Median Values of Baseline Parameters and Paths of Variables by Income Group

Parameter/Variable		Note	HI	UMI	LMI	LI
		A. Capital and investment—group medians*				
Labor share β		(1)	0.561	0.450	0.503	0.520
Public capital share of total capital K^{Gm}/K			0.277	0.356	0.330	0.440
Capital-to-output ratio (Measured)	Total K_0/Y_0	(2)	3.110	2.706	2.722	2.208
	Public K_0^{Gm}/Y_0	(3)	0.863	0.965	0.900	0.972
	Private K_0^P/Y_0	(3)	2.247	1.741	1.822	1.235
Depreciation rate	Total δ		0.040	0.038	0.042	0.035
	Public δ^G		0.020	0.020	0.020	0.020
	Private δ^P	(4)	0.047	0.048	0.053	0.047
Public investment share of total investment I^G/I		(7)	0.177	0.219	0.243	0.369
Investment-to-output ratio	Total I/Y	(5)	0.223	0.223	0.236	0.201
	Public I^G/Y	(6)	0.039	0.049	0.057	0.074
	Private I^P/Y	(6)	0.183	0.174	0.179	0.127
No. of countries			*48*	*29*	*19*	*12*
		B. The return to investment (with ϕ = 0.17; ζ = 1)*				
Marginal product of measured public capital $MPK^{Gm} = \phi/K_t^{Gm}/Y_t$			0.197	0.176	0.189	0.175
Return to *public* investment ($MPK^{Gm} - \delta^G$)			0.177	0.156	0.169	0.155
Marginal product of *private* capital $MPK^P = (1-\beta-\phi)/(K_t^P/Y_t)$			0.120	0.218	0.180	0.251
Return to *private* investment ($MPK^P - \delta^P$)			0.072	0.170	0.127	0.204

For a general description of the sources of data, see table 2.3. The sample size for all variables is guided by the consistent availability for individual countries of PWT 8.1 data for labor share, capital-to-output ratio, human capital growth, and TFP growth. See appendix 3, table A3.1 for median values of other key variables used in the simulations.
Countries are classified according to the 2018 World Bank classification of countries by income for the 2017 calendar year.
* Multiply by 100 (except values in ppts) to obtain parameter/variable values in percentage share or growth terms (%).
Note:
(1) For β, individual country values below 0.45 were increased to 0.45, and those above 0.70 reduced to 0.70.
(2) For K_0/Y_0, individual country values below 1.5 were increased to 1.5, and those above 3.5 reduced to 3.5.
(3) K_0^{Gm}/Y_0 and K_0^P/Y_0 are derived based on the median values of K_0/Y_0 and K^{Gm}/K.
(4) δ^P is derived based on the median values of δ, δ^G and K^{Gm}/K.
(5) Median of 15-year averages across countries over 2001-2015. I/Y is gross fixed capital formation (% of GDP) from WDI, except for Qatar, for which the same variable is tabulated from the IMF FAD Investment and Capital Stock Database.
(6) I^G/Y and I^P/Y are derived based on the median values of I/Y and I^G/Y.

The second answer is that developing countries have a shortage of public capital relative to their development aspirations, but not relative to their current development level. That is, people in low-income countries have many unmet needs, with public infrastructure capital being in just as short supply as everything else.

As the "usefulness" of public capital does not vary with income (Calderon, Moral-Benito, and Serven 2015), the stability of the public capital-to-output ratio across income levels also means that the marginal product of measured public capital (MPK^{Gm}) is not relatively larger in developing countries. As we will see in the next section, this is the effect of an expansion of public investment on growth in the short run, with unchanged efficiency. Specifically, we find that with our relatively generous calibration of usefulness ($\phi = 0.17$), that the MPK^{Gm} is around 18.5% (±1%), which varies inversely with the public capital-to-output ratio (table 2.5, panel B). After subtracting the depreciation rate of 2% (constant across countries), this yields a return to new public investment of around 16.5% (±1%) which also does not vary systematically across levels of development. The relatively high absolute returns stem from the high assumed usefulness of public capital in our default calibration. If instead we assumed $\phi = 0.1$ (for public buildings), then the return to public investment falls to around 9% (±1%), though the ranking across income groups is unchanged.

While some might interpret the lack of a higher return to public investment in LI countries as a negative, we are more sanguine. The lack of a low return also means that development banks need not refrain from lending for infrastructure projects in countries with poor implementation capacity—as they are often encouraged to do—because that low capacity also means the projects are even more in need.[32]

In contrast, it seems that LI countries have a shortage of private capital for their level of development, and the scarcity of private capital falls with per capita income. Specifically, K^P/Y is around 1.25 for LI countries, around 1.80 for middle-income (MI) countries and 2.25 for HI countries (80% higher than that of LI countries). Measured public capital is also the largest share of total capital in LI countries (44%) and the lowest share in HI countries (28%). This reflects the fact that private financial markets are typically underdeveloped in LI countries and so the private sector finds it difficult to raise funds for investment. In some countries insecure property rights also reduce the incentive to invest in the first place.

A consequence is that the marginal product of private capital is the highest in LI countries (25%), which is double that in HI countries (12%), with MI countries in between. Note that the MPK^P does not vary exactly inversely with the K^P/Y across income groups, because of cross-country variation in the capital share $1-\beta$.[33] After subtracting depreciation (around 5%), the return to private investment is the highest in LI countries (around 20%), lower in MI countries (13–17%) and lowest in HI countries (7%). Interestingly, the return to private capital for LI countries is actually higher than for public investment (20% versus 16%), suggesting that if savings are scarce, governments need to be careful that public investment does not crowd out private investment.

As today's capital stocks reflect past investment, one might expect that public investment would make up a larger share of total investment in LI countries—which is exactly what we find. Public investment is 37% of total investment in LI countries, double the share in HI countries (18%), with MI countries in between (23%).[34] Translated to a share of GDP, public investment spending decreases steadily with income per capita: 4% of GDP in HI countries, 5% in UMI countries, 6% in LMI countries, and 7% of GDP in LI countries. Keefer and Knack (2007) argue that this is likely due to poor quality governance in developing countries, rather than the level of income per se. Consistent with earlier results, private investment is particularly lacking in LI countries—around 13% of GDP versus 17–18% of GDP in the other three income groups.

6.2 The effect of an increase in public investment on growth

Figure 2.3 shows the effect of a permanent 1ppt GDP increase in public investment on growth. In the year following the shock, growth increases by the marginal product of measured public capital (equation 16A with $\theta_t^N = \theta_t$), which as argued above is around 0.17–0.19ppts and is surprisingly similar across countries with different levels of development (orange (circles) line with $\phi = 0.17$, congestion specification ($\zeta = 1$)).

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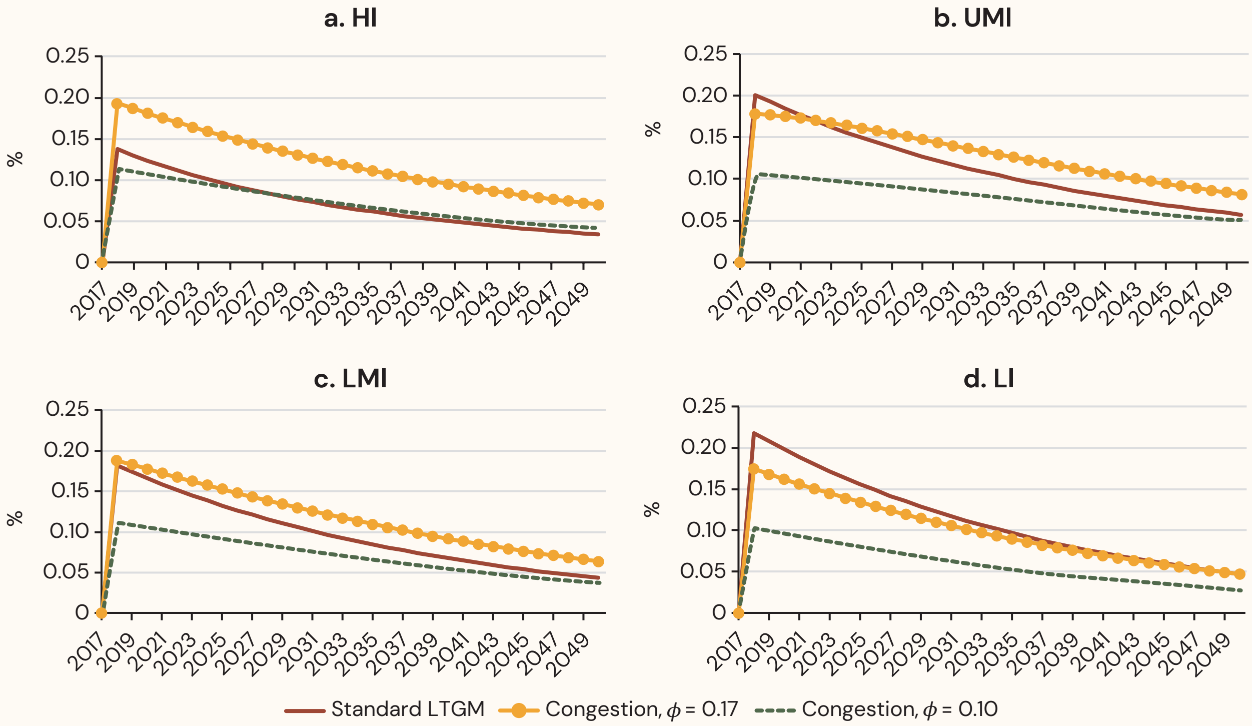
[32] For example, Keefer and Knack (2007) argue that their "results therefore signal the need for donor agencies to exercise particular caution in supporting public investment in countries with a weak institutional environment."

[33] The return to private capital is even higher with $\phi = 0.1$ (though its ranking across groups is unchanged), as the penalty for reducing the congestion of public capital is lower.

[34] These figures are average investment rates over 2001–2015. In steady state $K^j/Y = I/Y = (g^y + \delta^j)$ for $j = G,P$. If the countries in table 2.5 were in steady state, headline GDP growth rates would need to be ≈3% for HI countries, ≈3.8% for UMI countries, ≈4.8% for LMI, and ≈5.6% for LI countries, which are fairly close to what we observe.

Figure 2.3: Incremental Output Growth from a 1 ppt increase in Public Investment in the LTGM-PC (congestion, $\zeta = 1$)



The second thing to note from figure 2.3 is that the increment to growth falls over time. This is because as public capital accumulates, K^{Gm}/Y increases, which reduces the marginal product of measured public capital. This is intuitive: one would expect an increase in public investment to become less effective in boosting growth over time as "infrastructure needs" are met. There is some heterogeneity across income groups: the boost to growth is slightly less persistent in LI countries. If these countries had a lower capital share $(1-\beta)$, the marginal product of private capital which is "crowded in" would decline more quickly (in addition to marginally higher K^{Gm}/Y which means the marginal product of public capital dwindles faster over time). However, there is little evidence LI countries have a lower capital share.

Finally, the effect of an increase in public investment in the LTGM-PC (with $\phi = 0.17$ and $\zeta = 1$) is, on average, similar to the effect of a same-sized increase in aggregate investment in the Standard LTGM (brown solid line) for all but HI countries. Specifically, the effect in the LTGM-PC is very similar to the Standard LTGM for MI countries, slightly lower for LI countries, and higher for HI countries. The latter is because HI countries tend to have the lowest share of total capital owned by the public sector. The effect of public investment on growth is naturally much smaller in the LTGM-PC when $\phi = 0.10$ (dashed green line), but is also much smaller than the comparable effect in the Standard LTGM (except in HI countries). Greater consistency with the Standard LTGM is one reason we prefer the $\phi = 0.17$ calibration over the $\phi = 0.10$ calibration.[35]

[35] With the pure public good setting (appendix 3, graph A3.1), the immediate effect of higher public investment is broadly similar to that of the congestion setting, but is more persistent.

6.3 The effect of private investment on growth

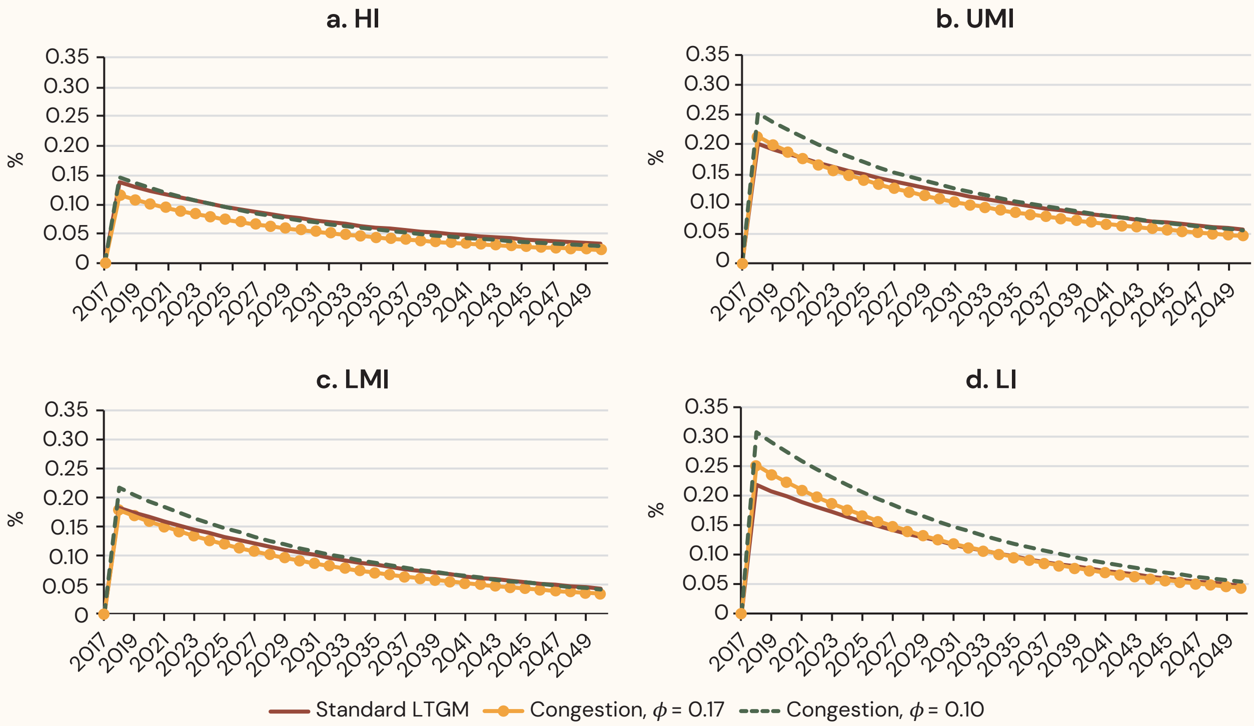
Figure 2.4 reports the effect of a 1ppt of GDP expansion in *private* investment on growth, which is largest for LI countries. In the first period following the shock, growth increases by the MPK^P (equation 16B), which as argued above is twice as large for LI countries as HI countries (25ppts versus 12ppts). As before, the increase in growth falls over time as private capital accumulates, raising K^P/Y and lowering the marginal product of additional private capital. Nonetheless the effect of higher private investment on growth is quite persistent, verifying our claim above that developing countries are particularly short of private capital.

Comparing different parameterizations: with the congestion specification, a lower ϕ increases the effective output elasticity of private capital $(1 - \beta - \phi)$ as it reduces the strength of congestion— increasing the effect of private investment on growth. On average, the increment to growth of private investment is similar with the Standard LTGM (and slightly closer with $\phi = 0.17$). With the pure public good setting (appendix 3, graph A3.2), the effect of an increase in private investment is much larger than with the congestion specification, and much larger than the Standard LTGM.

6.4 In which countries is public or private investment more effective for boosting growth?

The previous two subsections allowed us to compare the effects of investment (public and private) in the LTGM-PC for income group medians. But countries within each income group are highly heterogenous. What determines whether private or public investment has a larger effect on growth in the LTGM-PC for individual countries?

Figure 2.4: Incremental Output Growth from a 1 ppt increase in Private Investment in the LTGM-PC (congestion, $\zeta = 1$)



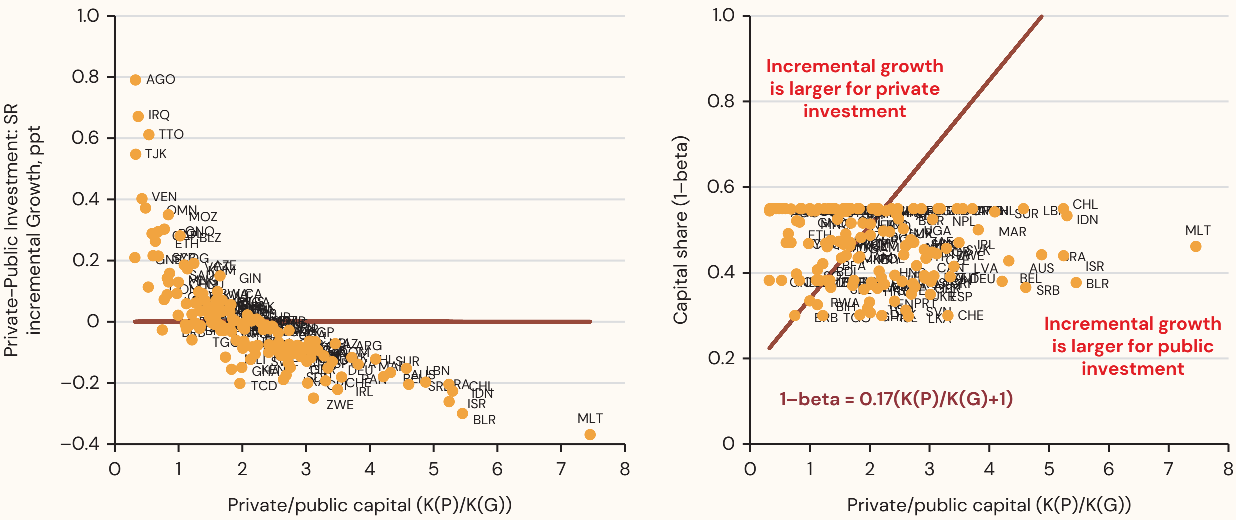
In the **short run,** based on equations (16A) and (16B), the difference in the short-run boost to growth from similar increments to private and public investment-to-output ratios, respectively is given by equation (25). One can see that short-run return to private investment is larger if $(1-\beta-\zeta\phi)/\phi > K_t^P/K_t^{Gm}$. This condition is violated (with public investment generating a larger increase in growth) when public investment is relatively *useful* (high ϕ relative to $1-\beta$) and public capital is relatively *scarce* (high K_t^P/K_t^{Gm}). One can see this as the lower right region of figure 2.5(b).[36]

$$\underbrace{\frac{\partial g_{y,t+1}^{PC}}{\partial I_t^P/Y_t}}_{Private} - \underbrace{\frac{\partial g_{y,t+1}^{PC}}{\partial I_t^G/Y_t}}_{Public} = \frac{Y_t}{K_t^P}\left[(1-\beta-\zeta\phi)-\phi\left(\frac{K_t^P}{K_t^{Gm}}\right)\right] \tag{25}$$

The increment to growth from private investment in the short run is higher than that for public investment whenever private capital stock is approximately less than double the public capital stock (figure 2.5(a)), with $\phi = 0.17$ and $\zeta = 1$). This occurs for 40% of countries, and the median K^P/K^{Gm} of countries with a higher effect of private investment is 1.26. As the marginal product of private capital is higher in the pure public good setting (since there is no congestion), the return to private investment is naturally higher. Specifically, under the pure public good setting (see appendix 3, graph A3.3 (i)), the increment to growth from private investment is higher for two-thirds of countries, and the median K^P/K^{Gm} of countries with a higher increment is 1.60.[37]

In the **long run,** the increment to growth from private investment is higher for only a quarter of countries, and for those countries the private and public capital stocks are roughly the same size (figure 2.6, $\phi = 0.17$, $\zeta = 1$). Under the pure public good setting (see appendix 3, graph A3.4(i)), the increment to growth from

Figure 2.5: Private Investment Versus Public Investment in the LTGM-PC - Differences in Short-Run Incremental Output Growth ($\phi = 0.17$, congestion, $\zeta = 1$)

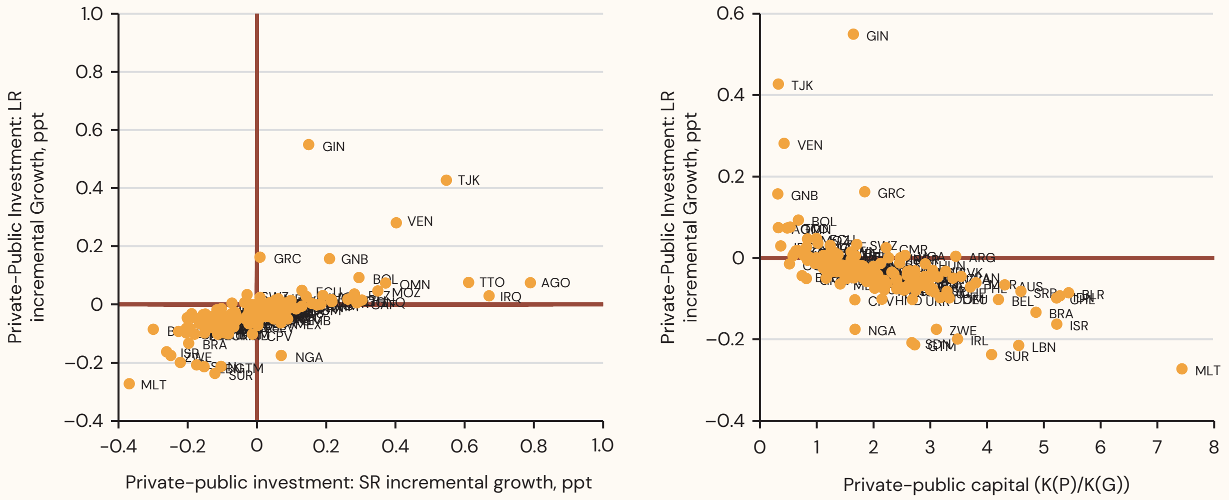


Analytical Difference: $\frac{Y_t}{K_t^P}\left[(1-\beta-\zeta\phi)-\phi\left(\frac{K_t^P}{K_t^{Gm}}\right)\right]$. See equation (25).

[36] Readers will note that this is a rearrangement of $(1-\beta-\zeta\phi)/\left(\frac{K_t^P}{Y}\right) > \phi/\left(\frac{K_t^{Gm}}{Y}\right)$, which is an equivalent condition that the marginal product of private capital is higher than the marginal product of public capital.

[37] When $\phi = 0.10$, more countries record a higher increment to growth from private investment: 84% of countries under the congestion setting (see appendix 3, A3.3(ii)).

Figure 2.6: Private Investment Versus Public Investment in the LTGM-PC - Differences in Long-Run Incremental Output Growth (ϕ = 0.17, congestion, ζ = 1)



private investment is higher for around 40% of countries, and the median K^P/K^{Gm} of countries with a higher increment is 1.24.[38]

Overall, for our sample of countries and calibration, public investment has stronger effects on growth than private investment for most countries, assuming that the elasticity of output to public capital is relatively high (ϕ = 0.17) The approximate cut-off where public investment tends to have stronger effects is when $K^P/K^{Gm} > 2$ (or equivalently, $K^{Gm}/K^P < 0.5$).[39] In the short run, the boost to growth from public investment is only larger than for private investment for most countries when there is congestion.

6. 5 The efficiency of public investment

6.5.1 Stylized facts

One of the reasons that public capital might have less effect on growth in developing countries is that it is inefficient. However, as already noted in section 2, the *level* of efficiency θ does not affect the marginal product of measured public capital and the effect of additional public investment on growth. For low efficiency countries, only a fraction of new investment might become productive capital, but this is offset by the greater need for public capital given that past investment was also inefficient.[40] However, this does not mean that *increasing* public investment efficiency cannot have a large effect on growth.

The potential for higher growth through greater efficiency of public investment depends on current efficiency being low. In the first row of table 2.6, we calculate the median of the Infrastructure Efficiency Index (IEI) for each income group (see section 4 for details on the construction of the IEI). As expected, based on the full set of computed IEI, HI countries have the highest median efficiency, with around 87% of roads

[38] When ϕ = 0.10, more countries would record a higher increment to growth from private investment (see appendix 3, graph A3.4(ii)).

[39] Angola and Iraq are outliers in figures 2.5(a) and 2.6(a), which may reflect that both have been involved in long drawn-out conflicts. See footnote 25, for a further discussion of how K/Y ratios might be affected by war/conflict.

[40] Berg et al. (2015) show that for the Cobb-Douglas production function (as used here), these two are exactly offsetting. However, even with the Constant Elasticity of Substitution (CES) production function the two factors are mostly offsetting unless public and private capital are extremely complementary (their figure 2.3).

Table 2.6: Efficiency—Income Group Medians (with ϕ = 0.17; ζ = 1)

Parameter/variable	HI	UMI	LMI	LI
Efficiency of public capital stock θ	0.870	0.753	0.730	0.590
*No. of countries***	*21*	*25*	*27*	*10*
Efficient public capital-to-output ratio $G_0/Y_0 = \theta K_0^{Gm}/Y_0$	0.751	0.726	0.656	0.574
Marginal product of *efficient* public capital $MPK_e^G = \left[\frac{\phi}{\theta_t K_t^{Gm}/Y_t}\right]$	0.226	0.234	0.259	0.296
Marginal product of efficiency $MPe = \phi\left[\frac{I_t^G/Y_t}{\theta_t K_t^{Gm}/Y_t}\right]$	0.009	0.011	0.015	0.022
$\mu = I^G/Y/\theta$ = ppts increase in I^G/Y equivalent to 1ppts increase in θ^N after one year (also equivalent by 2040)	0.045	0.065	0.079	0.125

For a general description of the sources of data, see table 2.3.
Countries are classified according to the 2018 World Bank classification of countries by income for the 2017 calendar year.
* Multiply by 100 (except values in ppts) to obtain parameter/variable values in percentage share or growth terms (%).
** Number of countries for efficiency θ is based on IEI data.
Calculations for $\theta K_0^{Gm}/Y_0$, MPK_e^G, MPe and μ, are formed by combining the data in table 2.5 with the efficiency θ for each income group (not on a constant group of countries).

being paved or water/electricity reaching their final destination. For MI countries, efficiency is about 74%, or one-seventh lower. Efficiency is the lowest for LI countries, where only 59% of roads are paved or water/electricity reach their final destination; which is about one-third lower than efficiency in HI countries.

One can also use the IEI to calculate the *efficient public capital-to-output ratio* $\theta K_0^{Gm}/Y_0$. Because the public capital-to-output ratio (K_0^{Gm}/Y_0) is roughly constant across levels of development, but efficiency θ increases with development, the combined efficient public capital-to-output ratio also increases with development. Specifically, the efficient public capital-to-output ratio is around 0.75 in HI countries, 0.73 in UMI countries, 0.66 in LMI countries, and 0.57 in LI countries. This suggests that LI countries do not have a shortage of measured public capital (as argued above), but rather a shortage of *efficient* public capital.

How should we interpret the efficient public capital to output ratio $\theta K_0^{Gm}/Y_0$ for policy? Equation (26) is the *marginal product of efficient public capital* (MPK_e^G) — the effect of an extra ppt of GDP of efficient investment $\theta_t^N[I_t^G/Y_t]$ on growth (the derivative of equation 16 with respect to $\theta_t^N I_t^G/Y_t$). One can see that the MPK_e^G is inversely proportional to the efficient public capital-to-output ratio $\theta K_0^{Gm}/Y_0$. As such, a low efficient public capital-to-output ratio means that the return to an extra *efficient* unit of public investment is high.

$$MPK_e^G \equiv \frac{\partial g_{y,t+1}^{PC}}{\partial[\theta_t^N I_t^G/Y_t]} = \frac{\phi}{\theta_t K_t^{Gm}/Y_t} \tag{26}$$

Because LI countries have the lowest $G_t/Y_t = \theta K_0^{Gm}/Y_0$ they also have the highest $MPK_e^G = 30\%$, which is almost *double* the regular marginal product of public capital from section 6.1. In contrast, MI countries have a MPK_e^G of about 25%, while HI countries, a lower MPK_e^G of 23%.[41] The high MPK_e^G means that if a typical LI country (with low efficiency) were somehow able to invest efficiently, the returns for growth would be very high. But this is a hypothetical scenario. As Berg et al. (2015) and others point out, quickly increasing

[41] The large absolute size of the MPK_e^G stems from the generous calibration of usefulness (ϕ = 0.17). Instead, with ϕ =0.10, the MPK_e^G falls to 17% for LI countries, and 14–15% in MI and 13% HI countries.

public investment implementation capacity is difficult, largely because public investment capacity has deep determinants, such as poor institutional quality and a lack of relevant bureaucratic human capital.

6.5.2 Increasing efficiency ("investing in investing")

However, it can still be that the efforts to improve efficiency are highly costeffective, even if they only lead to a slow increase in the average quality of the public capital stock. Here we consider the effect on growth of a 5ppt increase in the efficiency of new public investment from 2017 onwards (figure 2.7), which is roughly a one-sixth of the gap between the efficiency of low- and high-income countries (first row, table 2.6). We also assume public investment for each income group is at its group median from table 2.5, panel A (3.9% for HI countries, through to 7.4% for LI countries). Average efficiency reflects characteristics of the installed public capital stock, and so changes only take place slowly. The effect on growth is strongest for the representative LI country given its low-quality stock, where increased efficiency boosts growth by 0.11ppts.[42] For MI and HI countries, the average efficiency levels are much higher, and so the boost to growth is much smaller—around 0.05ppts for UMI and HI countries (with $\phi = 0.17$), and 0.075ppts for LMI countries.[43] For LI countries, "catch up" is easier because practices are so far from the frontier.

What determines the increase in growth from an extra unit of efficiency in the short run? Taking the derivative of equation 16 with respect to θ_t^N, produces the *marginal product of efficiency* (*MPe*), which is the boost to growth from a 1ppt increase in the efficiency of new public investment (θ_t^N):

$$MPe \equiv \frac{\partial g_{y,t+1}^{PC}}{\partial \theta_t^N} = \phi \left[\frac{I_t^G / Y_t}{\theta_t K_t^{Gm} / Y_t} \right] \tag{27}$$

In table 2.6, one can see that the *MPe* is highest in LI countries (0.022), which is more than double the rate in HI (0.009) countries. UMI and LMI countries are in-between (0.011 and 0.015, respectively). As such a 5ppt immediate increase in θ_t^N: for LI countries will raise growth by 0.022 × 5ppts = 11ppts, which is similar to the boost to growth in the first period in figure 2.7. For HI countries, in contrast, a 5ppt increase in efficiency would raise growth by a much lower 5ppts (0.009 x 5ppts). The *MPe* is inversely proportional to the *efficient public capital-to-output ratio*, is increasing in the usefulness of public capital (ϕ) and also increasing in the public investment to output ratio (I_t^G / Y_t).

This last somewhat surprising result is because an increase in efficiency θ_t^N only affects new investment. Intuitively, in countries with low public investment rates, an increase in the efficiency of new public investment will only have a small short-run effect on the average efficiency of installed capital—and hence on growth—because the new efficient public capital is only a small fraction of the total capital stock. In these countries, a permanent increase in the efficiency of public investment will still boost output, but it will just take more time for these gains to materialize.

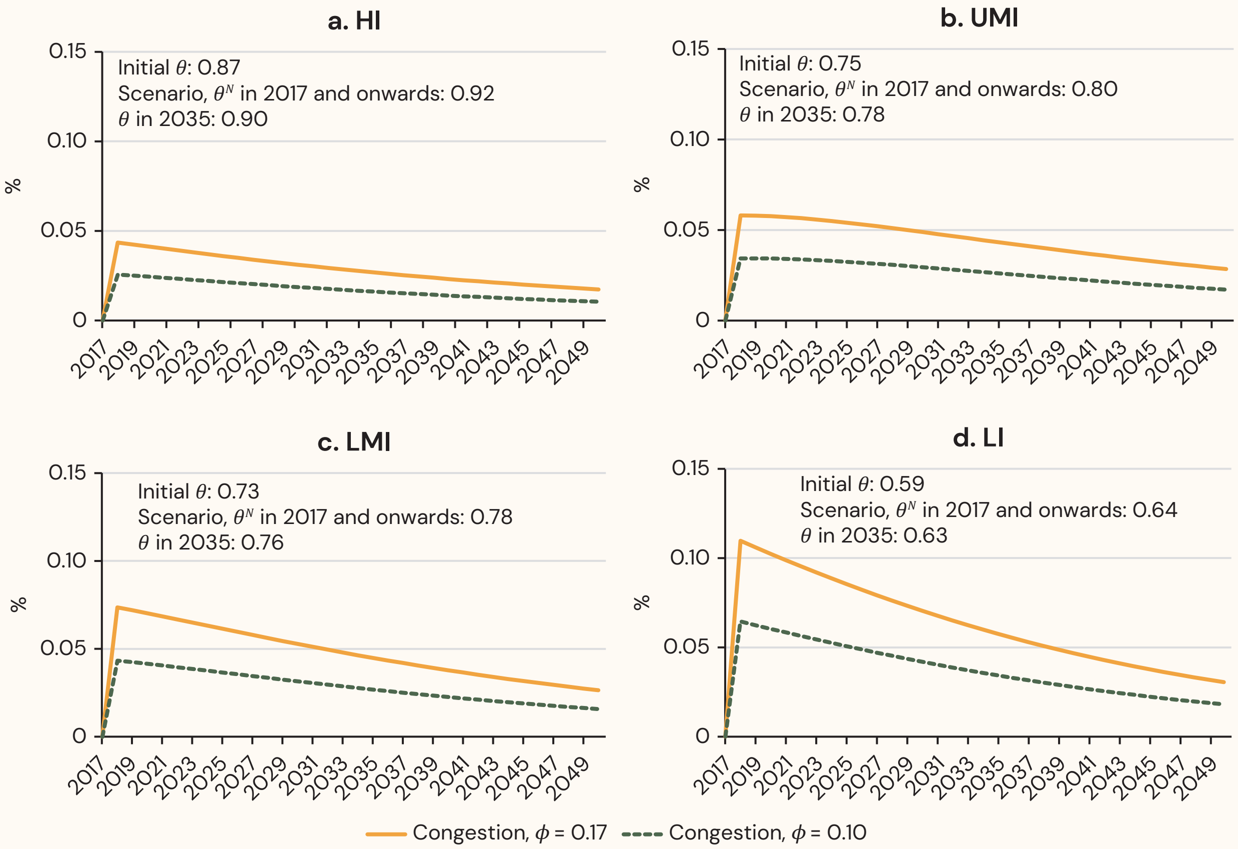
6.5.3 Which countries should invest in an increase in the quantity versus quality of public investment?

One can compare the effect on growth of an extra unit of public investment (equation (16A) at constant efficiency), and the return to an extra unit of efficiency (equation (27)). As the two are in different units, it is not appropriate to assess which marginal product is larger (as we did with private and public investment).

[42] Low base efficiency is important because it is the percentage (not percentage point) increase in efficiency that determines the effect on growth. A fixed 5 ppts increase in efficiency is a larger proportion of a low base.

[43] As ϕ is the elasticity of output with respect to *efficient* public capital, the effect of an increase in the efficiency is much lower with $\phi = 0.10$ than with $\phi = 0.17$.

Figure 2.7: Incremental Output Growth from a 5-ppt. Increase in the Efficiency of Public Investment in the LTGM-PC (congestion, $\zeta = 1$)



Instead, we calculate the size of the increase in the public investment rate (μ_{SR} ppts of GDP) equivalent to a 1ppt increase in efficiency. The larger the value of μ_{SR}, the more effective an increase in investment quality is at boosting short-run growth (relative to boosting the quantity of investment). Setting $MPe = \mu_{SR} \times MPK^{Gm}$ (from equations (27) and (16A)):

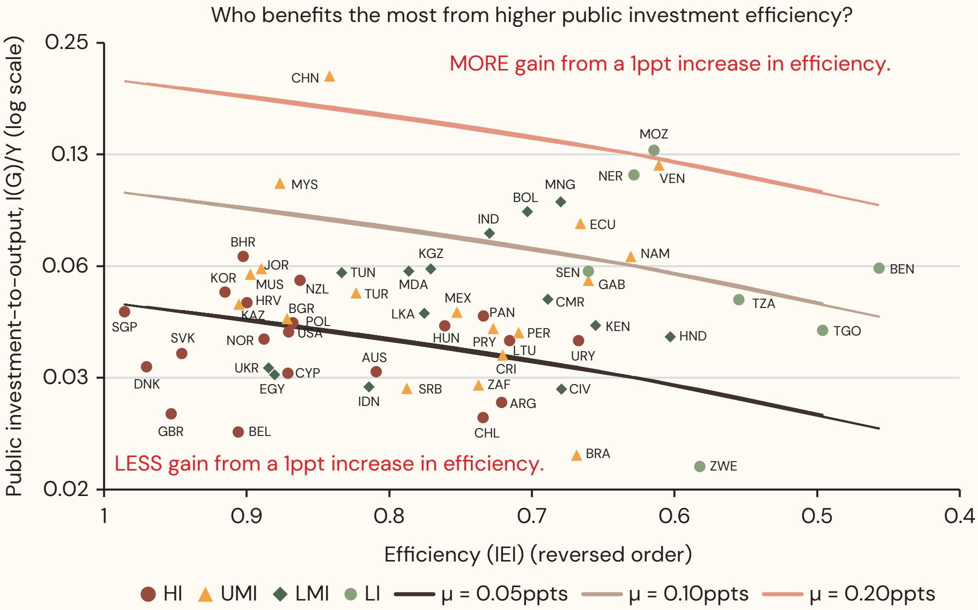
$$\phi\left[\frac{1}{\theta_t}\frac{I_t^G/Y_t}{K_t^{Gm}/Y_t}\right] = \mu \times \phi\left[\frac{1}{K_t^{Gm}/Y_t}\right] \tag{28}$$

A nice feature of this comparison is that it does not depend on measured public capital scarcity (K_t^{Gm}/Y_t), or the usefulness of public capital (ϕ), which cancel out in equation (28). That is, greater scarcity and usefulness increase MPe and MPK^{Gm} proportionately and so do not affect the relative effectiveness of quality versus quantity (though they do affect the aggregate size of both marginal products). Rearranging implies:

$$\mu_{SR} = \frac{I_t^G/Y_t}{\theta_t} \tag{29}$$

Equation (29) suggests that increases in investment quality are particularly effective in (i) countries with a high rate of public investment (because only new investment is affected by the improved investment management processes), and (ii) countries with low existing quality of public capital (so the improvement

Figure 2.8: Quantity versus Quality of Public Investment



in quality is larger in percentage [not percentage point] terms). For LI countries, $\mu_{SR} = 0.13$ ppts of GDP, that is a 1ppt increase in the quality of public investment, has the equivalent effect on short-run growth as a 0.13ppts increase in quantity of public investment. Given that improving investment processes could be almost free (if feasible), saving 0.13ppts of GDP on public investment expenditure for the same short-run growth outcome is good policy. Of course, improvements in quality are not as powerful elsewhere. For MI countries, an extra unit of efficiency is worth $\mu_{SR} \approx 0.07$ppts of GDP of public investment, and for HI countries (with the lowest I_t^G/Y_t and highest quality θ) $\mu_{SR} = 0.05$ppts.

For individual countries with available data on IEI and public investment, figure 2.8 plots the size of recent public investment-to-output ratios (15-year average, 2001–2015) on the y-axis, and existing quality (as reflected by the IEI) on the x-axis. The further a country is toward the top right of the figure, the more effective a 1ppt increase in investment *quality* is relative to greater investment *quantity*. Lines represent the locus of points for $\mu = 0.05$ppts, 0.1ppts or 0.2 ppts. Specifically, many LI countries have public investment-to-output ratios that are greater than 5% and efficiency levels lower than 0.6 and so fit on the upper right-hand side with the most to gain. Most HI countries are on the lower left-hand side with high efficiency and low public investment rates, suggesting limited gains from higher efficiency. Outliers are China (CHN) and Malaysia (MYS), which appear to have relatively high efficiency levels (≈0.85) but can still make sizable gains given relatively high public investment ratios of 20% and 11% respectively. China and Mozambique benefit the most overall, where a 1ppt higher efficiency is equivalent to an ≈0.25ppts GDP increase in public investment.

Our calculations so far have involved the *short-run* increase in investment equivalent to a 1ppt increase in efficiency (μ_{SR}). Instead, one might be interested in the permanent increase in investment that generates the same increase in GDP per capita (GDPPC) by 2040 as a 1ppt increase in efficiency—what we call μ_{LR} Using numerical simulations we find that the values of μ_{SR} and μ_{LR} are almost identical. This is because the increase in efficiency (and equivalently sized increase in I^G/Y) is small, which means that any nonlinearities are second order.

7. Conclusion

In this chapter, we develop a new model of public investment and growth—the Long Term Growth Model Public Capital Extension (LTGM-PC)—which is designed to capture the effect of increases in public infrastructure investment quantity or quality on growth, while at the same time being simple enough to solve in a spreadsheet without macros (the Excel-based tool is provided as a companion to this chapter at the website www.worldbank.org/LTGM). Relative to the Standard Long Term Growth Model (LTGM), our extension allows public and private capital to enter the production function separately and for public capital to be of poor quality such that only a fraction can be used in production.

The effects of public and private investment on growth in our model vary substantially across countries depending on whether the country is relatively short of public or private capital—but on average are similar to the effect of aggregate investment in the Standard LTGM. We show analytically and numerically that the effect of public investment on growth is higher when the public capital-to-output ratio is lower—that is, when public capital is scarce. Conversely, in countries where public capital is abundant *relative* to other factors—even if it is scarce in absolute terms—public investment will have a smaller effect on growth. The growth impact is also larger when public investment is more *useful*, such as when it is in the form of essential infrastructure (public investment in other areas will have a lower return).

In contrast with several popular narratives, we find the growth impact of an increase in public investment is very similar across different levels of development. For a *typical* low- or middle-income country with our default parameters, a permanent 1ppt of GDP increase in public investment in essential infrastructure tends to boost growth by around 0.18ppts in the short term, but the boost to growth falls slowly over time as public capital accumulates. Other less useful types of public investment (like public buildings) have a boost to growth of around 0.1ppts. In contrast, a permanent 1ppt of GDP increase in private investment leads to a slightly higher short-term boost to growth of about 0.22ppts, although the effect tapers off faster over time.

Model simulations also show that there can be substantial growth dividends from improvements in the *quality* of new public investment. Our new Infrastructure Efficiency Index (IEI) suggests a public capital efficiency loss of about 30 ppts for low-income countries, and 10–15 ppts for middle-income countries (relative to the efficiency of high-income countries). For countries with poor quality public capital and a large public investment share of GDP—such as many low-income countries—an increase in the quality of public investment can be just as effective as a modest increase in quantity of public investment. For example, for the typical low-income country, a 1ppt increase in efficiency boosts growth by the same amount as a 0.13ppt of GDP increase in public investment. Despite this, the *level* of efficiency has no effect on the marginal product of public capital because the low quality of new public investment is exactly offset by a greater need for public capital due to the poor quality of past public investment (as in Berg et al. 2015).

In closing, it is worth mentioning a few caveats to our model and stylized facts. In order to keep the LTGM-PC as simple as possible, we abstract from the effects of the financing of public investment via distortionary taxation. In many cases this will act as a drag on growth, and so our growth impact should be seen as an upper bound in that context (unless public investment can be financed by reducing unproductive expenditure elsewhere). We also abstract from endogenous private investment and return-seeking international capital flows. These factors might lead to a larger crowd-in of private investment, but they could also amplify any negative impacts of distortionary taxation. Finally, our stylized facts depend on available data, and the quality of that data. While we have data on many high- and middle-income countries, the sample size for low-income countries is small, which might increase the volatility of our estimates.

Appendices and the LTGM-PC spreadsheet-based toolkit are available online at https://www.worldbank.org/LTGM.

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Chapter 3

Productivity Growth: Patterns and Determinants across the World[1]

Young Eun Kim and Norman V. Loayza[2]

Abstract

This chapter provides a productivity extension of the World Bank's Long Term Growth Model (LTGM). Based on an extensive literature review, the chapter identifies the main determinants of economic productivity as innovation, education, market efficiency, infrastructure, and institutions. Based on underlying proxies, the chapter constructs indexes representing each of the main categories of productivity determinants and, combining them through principal component analysis, obtains an overall determinant index. This is done for every year in the three decades spanning 1985–2015 and for more than 100 countries. In parallel, the chapter presents a measure of total factor productivity (TFP), largely obtained from the Penn World Table, and assesses the pattern of productivity growth across regions and income groups over the same sample. The chapter then examines the relationship between the measures of TFP and its determinants. The variance of productivity growth is decomposed into the share explained by each of its main determinants, and the relationship between productivity growth and the overall determinant index is identified. The variance decomposition results show that the highest contributor among the determinants to the variance in TFP growth is market efficiency for the Organisation for Economic Co-operation and Development (OECD) countries and education for developing countries in the most recent decade. The regression results indicate that, controlling for country- and time-specific effects, TFP growth has a positive and significant relationship with the proposed TFP determinant index and a negative relationship with initial TFP. This relationship is then used to provide a set of simulations on the potential path of TFP growth if certain improvements on TFP determinants are achieved. The chapter presents and discusses some of these simulations for groups of countries by geographic region and income level. In addition, as a country-specific illustration, the chapter presents simulations on the potential path of TFP growth for Peru under various scenarios. An accompanying Excel-based toolkit, linked to the LTGM, provides a larger set of simulations and scenario analysis at the country level for the next few decades.

JEL: D24, O33, I25, G14, H54, O43, O47.
Keywords: Productivity, innovation, education, efficiency, infrastructure, institutions, growth.

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[2] Young Eun Kim and Norman V. Loayza, World Bank. Corresponding author email: nloayza@worldbank.org. The views expressed herein are those of the authors and do not necessarily reflect the views of the World Bank, its Executive Directors, or the countries they represent. For helpful comments, we would like to thank Wen Chen, Steven Michael Pennings, Jorge Luis Guzman Correa, Zixi Liu, Ha Nguyen, Luis Servén, Rongsheng Tang, Yong Wang, and participants in seminars at the World Bank, the Federation of ASEAN Economic Associations, the Shanghai University of Finance and Economics, and Peking University.

"It is not by augmenting the capital of the country, but by rendering a greater part of that capital active and productive than would otherwise be so, that the most judicious operations of banking can increase the industry of the country." Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations* (page 131).

1. Introduction

With the same amount of inputs—including labor, human and physical capital, and materials—some countries, sectors, and firms produce more and others less. This difference depends on how productive they are in allocating and using resources in the production process. One of the most important lessons in economics is that productivity improvement is key to sustained economic growth. (See, among others, Hall and Jones 1999, Easterly and Levine 2001, and Caselli 2005.)

Productivity was a main concern of the fathers of modern economics, Adam Smith and David Ricardo, in the eighteenth century, as they considered the advantages of specialization and trade as the basis for the wealth of nations. In the first one-half of the twentieth century, as advanced economies started to recover from the Great Depression, Hicks (1939) and Schumpeter (1942) emphasized the importance of productivity improvements, linking them to enterprise renewal and "creative destruction." When economists turned their attention to developing countries, they described productivity growth as crucial in the search for sustained growth and development. For Lewis (1954), Kuznets (1957), and Chenery (1960), economic development required a structural transformation that shifted resources from less to more productive sectors of the economy. More recently, since the productivity slowdown in developed countries in the 1970s, the lackluster growth of developing countries in the 1980s, and the collapse of the communist regimes in Eastern Europe and East Asia in the early 1990s, interest in understanding the sources of growth and productivity has grown exponentially (see Woo, Parker, and Sachs 1997; Ben-David and Papell 1998; Easterly 2001; Jorgenson, Ho, and Stiroh 2008).

Placing the study of productivity in the context of economic growth research may bring about important insights. In the 1950s, Solow and Swan developed a growth model in which changes in physical capital, labor, and total factor productivity (TFP) determine the economy's growth rate (Solow 1956; Swan 1956). It has proven to be a workhorse of growth theory and applications for over 50 years. A drawback of this model, however, is that the path of TFP is assumed to be exogenous. At least since the mid-1980s, theoretical economists have addressed this shortcoming. For example, Romer (1987, 1990), Grossman and Helpman (1991), and Aghion, Philippe, and Howitt (1992) incorporated technological advances through research and development (R&D) as a driver of long-run growth. Lucas (1988) argued that the accumulation of human capital through education creates a positive externality that drives productivity, which in turn explains long-run growth. Rebelo (1991) included both human and physical capital in a composite measure that faces no decreasing returns, suggesting that continuous investment can lead to long-term growth. Barro (1990) and Barro and Sala-I-Martin (1992) incorporated tax-financed public goods and assumed that they complement private capital, so that concurrent investment in both public and private capital could lead to growth in the long run. Engerman and Sokoloff (2000) and Acemoglu, Johnson, and Robinson (2001, 2004) deepen the notion of public goods to argue that the role of political and economic institutions is fundamental to economic growth. It can be said that in all these cases, the proposed mechanisms driving productivity are ways of explaining economic growth in the long run without resorting to exogenous changes.

The interest in understanding the microeconomic foundations of aggregate behavior has also led to important insights on productivity. Hopenhayn (1992), Hopenhayn and Rogerson (1993), Caballero and Hammour (1996), and Davis, Haltiwanger, and Schuh (1996) pioneered research on the role of firm dynamics driving productivity and, consequently, economic growth. The conclusion from this extensive body of research is that resource reallocation (including firm entry and exit, innovation and renewal, and structural transformation) explains a substantial share of productivity improvement in the economy. Resource reallocation requires, however, a costly adjustment: the adoption of new technologies, the assimilation of production inputs by expanding firms, and the shedding of labor and capital by declining firms. Differences in the ease of resource reallocation can then explain why some countries are more productive than others. These differences can be related to the level of development of the country (e.g., a lack of human capital and functioning justice system; see Caballero and Hammour 1998 and Acemoglu and Zilibotti 2001) and to the quality of government's regulations and interventions (e.g., excessive labor regulations, subsidies to inefficient sectors, and barriers of firm entry and exit; see Parente and Prescott 2000). Although more refined in the mechanisms, the microfoundations literature points to the same conclusions as the aggregate literature highlighted above, regarding the roles of innovation, education, regulatory environment, and public goods and institutions in driving productivity.

The surge in theoretical research on economic growth and productivity has been paralleled by an enormous empirical literature. A selected review is offered in the second section of the chapter. In brief, this empirical research attempted to, first, test the validity of recent growth theories in contrast to (or in conjunction with) the neoclassical growth theory, and, second, determine the quantitative importance of various proposed drivers of growth. The first wave of empirical studies on new growth research focused on aggregate, cross-country data. In academic circles, this line of work is best exemplified by Barro's (1991) seminal study. In the World Bank and other policy-oriented organizations, empirical studies such as Easterly and Levine (1997, 2001), Loayza, Fajnzylber, and Calderón (2005), and Loayza and Servén (2010) offered a guide for understanding economic growth and its determinants, including policies and institutions. As micro-level data became more widely available in the 1990s, a second wave of empirical research used data at the industry and firm levels to study firm renewal, resource redistribution, and structural transformation. This led to insights and findings that could not have been obtained using country-level data, as shown in Foster, Haltiwanger, and Krizan (2001), Restuccia and Rogerson (2008), and Hsieh and Klenow (2009).

Considering numerous studies on economic growth and productivity published in the past few decades, in this chapter we take stock of the main conceptual conclusions surrounding productivity growth and synthesize the quantitative implications through original data collection and analysis. Apart from its independent contribution, this chapter serves as background for an extension of the World Bank Long Term Growth Model (LTGM, Chapter 1 of this volume). This extension quantifies how changes in TFP growth are driven by changes in its underlying determinants, and, in turn, how changes in TFP growth lead to different paths for economic growth.

The drivers of productivity growth can be grouped into five components (Kim, Loayza, and Meza-Cuadra 2016): *innovation*, to create and adopt new technologies; *education*, to spread these new technologies throughout the economy and to develop the capacity of the workforce to assimilate them; *market efficiency*, to promote the effective and flexible allocation of resources across sectors and firms; *infrastructure* (in transport, telecommunication, energy, and water and sanitation), to support and facilitate the economic activity of households, businesses, and markets; and *institutions* (in the regulatory, justice, policy, and political systems), to provide social and economic stability, defend property rights, and safeguard basic civil rights. These five components are interrelated and can clearly influence one another.

In this chapter we identify the main determinants of productivity growth, propose proxies to measure them, assess the pattern of TFP growth across regions and over time, and quantify the relationship between the TFP determinants proxies and TFP growth. For this purpose, we first conduct an extensive literature review on productivity that considers not only concepts and theories but also empirical studies. Then, we estimate TFP and construct indexes representing each of the five main determinants of TFP for a large group of countries in the past three decades (from 1985 to 2014). Finally, we measure the relative contribution of each of the main determinants to the variance of TFP growth, and we estimate their overall effect on TFP growth. As mentioned above, these results are used to build a TFP module for the extended Long Term Growth Model (LGTM).

In the rest of the chapter, section 2 presents a review of the literature; this is important because it not only frames the context of the chapter but also helps to identify and categorize the drivers of TFP growth. Section 3 describes the methodology, including the selection of countries and variables, the estimation of TFP, the construction of indexes to measure each TFP determinant category, and the variance decomposition and regression analysis. Section 4 presents and discusses the main results, from descriptive statistics to regression analysis. Section 5 uses the main results to generate simulations on the path of TFP growth if certain reforms are accomplished. Section 6 concludes.

2. Literature review

To identify and categorize the main determinants of TFP, we conduct a literature review spanning papers published from 1990 to 2016. We start with the reviews conducted by Isaksson (2007) and Syverson (2011) and expand the search further by using the key terms "total factor productivity," "economic growth," and "determinants." We filter papers based on abstracts and main texts, choosing those that present a quantitative relationship between productivity and its potential determinants, using evidence from developing and developed countries. We select papers that examine time-variant determinants that a country can improve either through market forces or by public policy decision and implementation. (See appendix A for the full list of the papers.) Based on the literature review, the main determinants of productivity are categorized into five components: innovation, education, market efficiency, infrastructure, and institutions (Kim, Loayza, and Meza-Cuadra 2016).

2.1 Innovation

Innovation, as the generation and adoption of new technologies, leads to the development of higher value-added activities, products, and processes and improves the performance of existing ones. Historically, a small number of countries have created new technologies based on investment in research and development (R&D) by the public and private sectors and an advanced level of human capacity and physical capital (Furman and Hayes 2004; Griffith, Redding, and Reenen 2004). Other countries have then adapted and adopted technological changes, with varying time lags and degrees of intensity (Comin, Hobijn, and Rovito 2008).

Using indicators such as investment in R&D, the number of patents, and the number of scientific and technological journal publications, many studies show that the creation or adoption of a new technology is positively associated with TFP growth (see, for example, Nadiri 1993; Chen and Dahlman 2004; Guellec and van Pottelsberghe de la Potterie 2004). For instance, Jorgenson, Ho, and Stiroh (2008) and Oliner, Sichel, and Stiroh (2008) show that Information and Communication Technologies (ICT) played a central role in accelerating productivity in the United States (U.S.) from the mid-1990s to the 2000s after the lackluster pace of productivity growth in the 1970s and 1980s. The comparison of Europe and the U.S. highlights the critical role of new technologies in expanding productivity. Ark, O'Mahony, and Timmer (2008) show that the productivity slowdown in Europe during the 1990s and 2000s is attributable to the lower contribution of ICT to growth, the smaller share of technology-producing industries, and slower advances in technology and innovation as compared to the U.S. Not only the development of new technologies but also the adoption of existing ones play a substantial role in enhancing productivity and income growth. Comin and Hobijn (2010) and Comin and Mestieri (2018), using data on the diffusion of more than 15 technologies across a large number of countries over the last two centuries, show that varying patterns of the adoption and diffusion of technologies since 1820 account for at least 25 percent of the income divergence across countries and 75 percent of the income difference between rich and poor countries.

2.2 Education

Education, as the knowledge and skills of the population, is essential to generate new technologies, as well as to disseminate, adapt, and implement them throughout the economy. Education allows workers not only to produce more and better, but also to expand and disseminate the technological frontier. For education to contribute to productivity, it must consist of strong basic foundations and sufficient specialization, rich in both quantity and quality, and spread throughout the population (Barro 2001; Hanushek and Woessmann 2015).

Studies suggest that indicators such as the number of schooling years and the completion rate of secondary and tertiary education of the population are associated with output growth through both TFP improvements and the direct contribution of human capital (Benhabib and Spiegel 1994; Griffith, Redding, and Reenen 2004; Bronzini and Piselli 2009; Erosa, Koreshkova, and Restuccia 2010). Having a sufficiently high level of education increases productivity growth in developing countries by enabling them to adopt new technologies from frontier countries. Benhabib and Spiegel (2005), for example, show that a country's average years of schooling (as a proxy for education) has a positive impact on TFP growth through technology catch-up. Miller and Upadhyay (2000) show that education (also using the years of schooling as a proxy) can affect how developing countries adopt new technologies through trade, with a positive impact on TFP. Barro (2001) shows in a study of around 100 countries that the quantity and quality of education, using the years of schooling and student test scores as respective proxies, are significantly related to economic growth. Wei and Hao (2011) show that education quality, using government expenditure on education and teacher-student ratios as proxies, is significantly associated with TFP growth in China.

2.3 Market efficiency

Market efficiency, defined as the efficient allocation of resources (e.g., labor, capital, and materials) across firms and sectors, enhances TFP by inducing unproductive firms to exit the market, facilitating productive firms to grow, and allowing new firms to emerge (Foster, Haltiwanger, and Krizan 2001; Hsieh and Klenow 2009; Parente and Prescott 2000; Restuccia and Rogerson 2017). Market efficiency has several components, including the proper functioning of output markets, financial systems, and labor markets.

A number of studies find that market efficiency is associated with a variation in productivity across firms, sectors, and countries. Jerzmanowski (2007) shows that inefficiency in the allocation of human and physical capital is the main explanation for the low-income level among around 80 countries from 1960 to 1995. Hsieh and Klenow (2009) estimate that, if capital and labor had been allocated at the relatively efficient level of the U.S., productivity in manufacturing sectors could have been 1.3 times higher for China and 1.6 times higher for India in 2005. Melitz (2003) shows that exposure to trade induces more productive firms to enter the export market and the least productive firms to exit, leading to an increase in aggregate industry productivity growth. The quality of the regulatory framework matters significantly for the ease of resource reallocation, including firm dynamics and structural transformation (Djankov et al. 2002; Loayza and Servén 2010). Drawing the link between shortcomings in technological adoption and burdensome regulations, Bergoeing, Loayza, and Piguillem (2016) argue that regulatory barriers of firm entry and exit account for 26 to 60 percent of the income gap between the United States and 107 developing countries and that not just removing these barriers but removing them jointly is critical. Nicoletti and Scarpetta (2003) and Arnold, Nicoletti, and Scarpetta (2008) show that burdensome market regulations, as well as and the lack of reforms for promoting private corporate governance and competition, caused industries that use or produce ICT to have meager productivity levels in several European countries and deterred firms from catching up to the international technological frontier.

Regarding financial systems, Rajan and Zingales (1998) show that financial development facilitates economic growth by reducing the costs of external finance to firms for a large number of countries in the 1980s. Beck, Levine, and Loayza (2000) argue that financial development affects economic growth mainly through its positive effect on TFP. Buera, Kaboski, and Shin (2011) show that financial frictions distort the allocation of capital and entrepreneurial talent across production units, adversely affecting TFP and sectoral relative productivity. With respect to labor markets, studies show that regulations that provide flexibility in the allocation of labor enhance productivity. Haltiwanger, Scarpetta, and Schweiger (2008) and Bartelsman, Gautier, and De Wind (2016) show that employment protection regulations preclude efficient labor reallocation because they curb job flows or discourage firms from adopting risky but highly productive technologies. Barro (2001) shows that the education of female students has an insignificant impact on economic growth unlike that of male students, suggesting that labor market reforms to incorporate female workers has a potential to increase TFP.

2.4 Infrastructure

Public infrastructure—in transport, telecommunication, energy, and water and sanitation—can provide timely and cost-effective access to input and output markets, workplaces, and knowledge and information sources, thus supporting all possible economic activities (Straub 2008; Galiani, Gertler, and Schargrodsky 2005). An appropriate infrastructure network—in terms of quantity, quality, and diversity—can complement private capital and labor, increasing their returns and impact on economic growth. In this way, expanding public infrastructure becomes a source of TFP growth.

The evidence that appropriate public infrastructure has a positive impact on productivity and economic growth is convincing. Hulten (1996) shows that 25 percent of the growth difference between East Asia and Africa over 1970−1990 is explained by the efficient use of infrastructure. Aschauer (1989) argues that public capital stock, especially core infrastructure such as highways, airports, sewers, and water systems, was critical in determining productivity in the U.S. over 1950–1989. Straub (2008) shows in a study of 140 countries over 1989–2007 that the infrastructure stock has a positive external impact on growth, for example, by allowing firms to invest in more productive machineries, decreasing workers' commuting times, and promoting health and education. Considering also a panel of countries over time, Calderón and Servén (2010, 2012, 2014) argue persuasively that infrastructure can have positive effects on both growth and distributive equity. These beneficial effects, however, require a framework that regulates, organizes, and coordinates the governments and companies that build public infrastructure and provide its services. Moreover, as highlighted by Pritchett (1996) and Devadas and Pennings (2018), the amount of infrastructure spending is not necessarily an indication of effective infrastructure investment. The quality of spending matters, and this seems to be highly related to the strength of public institutions (World Bank 2003, 2017r).

2.5 Institutions

Public institutions—in the regulatory, justice, policy, and political systems—can promote social and economic stability, provide a safe living and working environment, defend property rights, and safeguard basic civil rights. The environment and policies that public institutions provide have a large, fundamental impact on economic development (North 1990; Acemoglu, Johnson, and Robinson 2004). The evidence that good governance (reflected in political stability, the rule of law, the protection of property rights, bureaucratic quality, transparency and accountability, and the absence of corruption) has a positive effect on productivity and economic growth is large, comprehensive, and convincing.

Barro (1991) shows in a study of around 100 countries for 1960–1985 that economic growth is positively related to political stability and inversely to government-induced market distortions. Using ethnolinguistic fractionalization as an instrumental variable for measures of government corruption, Mauro (1995) finds that corruption has a statistically significant and economically large negative effect on economic growth. Knack and Keefer (1995) find that property rights, proxied by contract enforceability and risk of expropriation, has a substantial impact on economic growth, even after accounting for capital accumulation. Rodrik, Subramanian, and Trebbi (2004) show that the quality of institutions, measured by a composite indicator of the protection of property rights and the rule of law, has a positive impact on income levels across a large sample of countries. Chanda and Dalgaard (2008) find that the quality of institutions (proxied by a composite index of the rule of law, bureaucratic quality, corruption, the risk of expropriation, and the government repudiation of contracts) is positively related to productivity. Easterly and Levine (2003) show that institutions are channels for geographical endowments to have an impact on economic development. They also show that when institutional quality is controlled for, macroeconomic policies do not account for development, implying good governance leads to conducive macroeconomic environments.

The five categories of TFP determinants presented above span a comprehensive array of factors driving productivity. They are also the channels through which other potential variables affect TFP. Some of them are time-invariant, such as historical origins and geographic conditions. Their effect is captured by our proposed determinants. For example, Rodrik, Subramanian, and Trebbi (2004) show that geography has an impact on incomes by influencing the quality of institutions. Other potential variables account for slow-moving processes, such as social mobility and income inequality. Their effect on TFP growth, however, can be explained by education, market efficiency, and governance. Consider, as an illustration, the following papers. Cingano (2014) shows that income inequality has a negative impact on economic growth by impeding skill development among individuals with poorer parental education background. Dabla-Norris et al. (2015) show that low-income households and small firms face difficulties in accessing financial services, which decreases economic growth. Hoeller, Joumard, and Koske (2014) argue that the lack of policies that provide more inclusive access to education, financial services, and labor markets leads to income inequality, and eventually lower economic growth.

3. Methods

First, we present the sample of countries and years included in the analysis. Second, we report how TFP growth at the country level is estimated. Third, we construct a set of indexes representing each of the main productivity determinants; we then obtain an overall index by grouping the indexes together. Fourth, we analyze the relationship between TFP growth and the proposed indexes of TFP determinants.

3.1 Sample

We conduct the statistical analysis using a sample of 98 developing and developed countries for the period 1985–2014. They are selected from the larger sample of countries featured in the Penn World Table (PWT) 9.0 and the World Bank World Development Indicators (WDI) databases. We exclude countries that do not have a minimal set of historical data for statistical analysis, countries that depend heavily on oil production (because the contribution of oil to output could result in a large overestimation of TFP growth),[3] and small countries, defined as those with a population of less than 2 million (in 2016) (World Bank 2017m).

For the descriptive analysis of TFP growth across regions and decades (in section 4.1), we add 16 countries for which data on the share of labor in income is missing in PWT 9.0 but available from the Global Trade Analysis Project (GTAP) 9.0 (Aguiar, Narayanan, and McDougall 2016). For the descriptive analysis of TFP determinants (in section 4.2), we additionally include 22 countries, which, though not having information

[3] Heavy dependence is defined as reliance on oil production for more than 32 percent of GDP on average during 2006–2015, which is 90th –100th percentile among 98 countries with positive oil rents (World Bank 2017j); Angola (45%), Congo, Rep. (46%), Equatorial Guinea (42%), Gabon (32%), Iraq (52%), Kuwait (47%), Libya (54%), Oman (37%), Saudi Arabia (44%), and South Sudan (45%).

to obtain TFP estimates, do have data for the proposed determinant indicators. For growth projections in the Long Term Growth Model (LTGM), we add back small countries, heavily oil dependent countries, and those for which we can complete missing data from other sources and additional assumptions; thus, the TFP extension of the LTGM can be applied to about 190 countries for growth projections.

We classify high-income countries that have been members of OECD for more than 40 years as the OECD group. The rest of the countries are classified by region and income. We use the average of GDP per capita (World Bank 2017e) over 1985–2014 to break the sample into income quintiles. Appendix Table B.1 shows the country list by region and income quintile groups, indicating their inclusion in the samples by type of analysis (descriptive and statistical), data source (PWT, GTAP, and WDI), and other characteristics (oil rent and population).

3.2 Construction of total factor productivity

Total factor productivity is commonly measured as a residual, that is, the portion of GDP that remains after accounting for the direct contributions of capital and labor inputs in total gross domestic product (GDP) (Barro and Sala-i-Martin 2004). The aggregate capital stock is usually computed through the perpetual inventory method, as the accumulation of gross physical investment (from a given initial capital stock), discounting the depreciation of existing stocks. Labor input can be calculated as the number of employed people, adjusted for human capital. The capital share is the fraction of total GDP used to pay for capital, and the labor share is the fraction of total GDP used to pay for labor. The shares of each factor of production are often assumed to be constant over time.

For the level of (relative) TFP, we use the estimate provided in Penn World Table (PWT) 9.0, labeled *rtfpna* (Feenstra, Inklaar, and Timmer 2015). This series is obtained by setting the TFP level of 2011 equal to 1, and then computing the remaining TFP levels backwards and forwards by applying the TFP growth rates. The TFP growth rates are obtained implicitly through the following equations:

$$\frac{RTFP_{jt}^{NA}}{RTFP_{jt-1}^{NA}} = \frac{RGDP_{jt}^{NA}}{RGDP_{jt-1}^{NA}} / Q_{jt,\, t-1},$$

$$\text{where, } Q_{jt,\, t-1} = \frac{1}{2}\left(LABSH_{jt} + LABSH_{jt-1}\right)\left(\frac{EMP_{jt}}{EMP_{jt-1}}\frac{HC_{jt}}{HC_{jt-1}}\right) + \left[1 - \frac{1}{2}\left(LABSH_{jt} + LABSH_{jt-1}\right)\right]\left(\frac{RK_{jt}^{NA}}{RK_{jt-1}^{NA}}\right). \quad (1)$$

$RTFP^{NA}$: TFP level, computed with $RGDP^{NA}$, RK^{NA}, EMP, HC, and LABSH

$RGDP^{NA}$: Real GDP at constant national prices

RK^{NA}: Capital stock at constant national prices

EMP: The number of people employed

HC: Human capital based on the average years of schooling from Barro and Lee (2013) and an assumed rate for primary, secondary, and tertiary education from Caselli (2005)

LABSH: The share of labor income of employees and self − employed workers in GDP

j: *country*, and *t: year*

For our analysis, we calculate annual TFP growth rates by differencing the log-transformed TFP levels of year t and t−1, $ln(rtfpna_t) - ln(rtfpna_{t-1})$.

As a robustness check, we calculate TFP mainly using data from the World Development Indicators database (instead of PWT). In appendix E, we compare the results (on descriptive statistics and econometric analysis) using this alternative TFP measure.

3.3 Construction of main determinant indexes

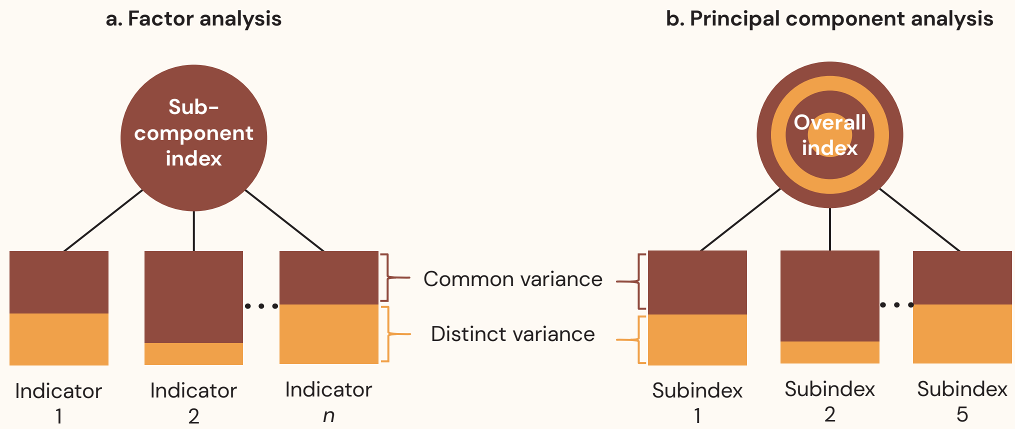
We construct subcomponent indexes that represent each of the five determinants—innovation, education, market efficiency, infrastructure, and institutions—and an overall index representing the five determinants all together. First, to construct a subcomponent index, we select relevant indicators and combine them using factor analysis, which captures as much of *common* variance in the indicators as possible in a single index (figure 3.1A) (Mulaik 2009).

Then, to construct an overall determinant index, we combine the five subcomponent indexes using principal component analysis (PCA), which captures as much of *total* variance in the five subcomponent indexes as possible in a single index (figure 3.1B) (Jolliffe 2002).[4] We use PCA for the overall determinant index because it is intended to represent the different features of each of the subcomponent indexes. This is unlike each subcomponent index, which is supposed to represent the common feature of its indicators.[5]

For each category of TFP determinants, we select indicators based on whether they measure an important characteristic, have been used in the literature, and have data available across countries and over time. In a few cases where most but not all information is available, we impute missing values based on income groups or trends, as explained at the end of this subsection.

Innovation. To construct a subcomponent index for innovation (*Innov*), we choose the following indicators: public and private expenditure on R&D as a percentage of GDP as an indicator of the effort to create new technologies (World Bank 2017o); and the number of patent applications by residents and nonresidents and the number of scientific and technical journal articles as indicators of the outcome of R&D activities (World Bank 2017k, 2017l, 2017p). *Education.* To construct a subcomponent index for education (*Educ*), we choose the following indicators: government expenditure on education as percentage of GDP as an

Figure 3.1: Comparison of Factor Analysis and Principal Component Analysis



Source: SAS 2017. The authors revised the original diagrams.

[4] We select a factor, or a principal component in the case of PCA, with an eigenvalue higher than 1. In our analysis, there is only one factor for each subcomponent index and one principal component for the overall index with an eigenvalue higher than 1.

[5] In order for the variables to enter factor/principal component analysis, they must have a sufficiently high degree of commonality. We run the Kaiser-Meyer-Olkin test to examine whether the indicators have enough common variance. A test value below the critical value of 0.5 means that an indicator or a group of indicators are unacceptable. For factor analysis, the test results show that the selection of indicators as a group is acceptable with a value of 0.60 for innovation, 0.69 for education, 0.63 for market efficiency, 0.83 for infrastructure, and 0.92 for institutions. The test results for individual indicators in each category are also above the critical value. For principal component analysis, used to construct the overall index, the test result is 0.88 for the group of the subcomponent indexes, and also above the critical value for each subcomponent index.

indicator of public investment in foundational human capital (World Bank 2017f); the shares of population aged 25 and over with completed secondary education and with completed tertiary education (Barro and Lee 2013) as indicators of educational attainment among workers; and a standardized international test score— a single average of scores in math, science, and reading on the Programme for International Student Assessment (PISA)— as an indicator of educational quality (OECD 2016a, 2016b, 2016c).

Market efficiency. To construct a subcomponent index for market efficiency (*Effi*), we classify markets into output, financial, and labor markets. We select the World Bank Doing Business scores as an indicator of output market efficiency, which measure the regulatory environment in terms of ease for firms to start a business, trade across borders, register property, get credit, and the like (World Bank 2017a). We choose the International Monetary Fund (IMF) Financial Development Index as an indicator of financial market efficiency, which measures the level of financial development by including the size and liquidity of financial markets, ease for individuals and firms to access financial services, and the ability of financial institutions to provide services at low costs with sustainable revenues (Svirydzenka 2016). As indicators of labor market efficiency, we construct an composite index, using factor analysis, consisting of minimum wage (% of value added per worker), severance pay for redundancy dismissals (weeks of salary), and the share of women in wage employment in the nonagricultural sector from World Bank databases (World Bank 2017h, 2017q).

Infrastructure. For a subcomponent index for infrastructure (*Infra*), we select fixed-telephone and mobile subscriptions (per 100 people) (World Bank 2017c, 2017i); the length of paved roads (km per 100 people) (International Road Federation 2017a, 2017b); electricity production (kw per 100 people) (OECD/IEA 2017); and access to an improved water source and improved sanitation facilities (% of population) (WHO/UNICEF 2017b, 2017a).

Institutions. To construct a subcomponent index for institutions (*Inst*), we select the World Bank Worldwide Governance Indicators. These include measures of voice and accountability (citizens' participation in selecting their government and freedom of expression); control of corruption (the extent to which public power is exercised for personal gain); government effectiveness (the quality of public services and policy formulation and implementation); political stability (the absence of politically motivated conflict); regulatory quality (the ability of government to formulate and implement regulations that promote private sector development); and the rule of law (the extent to which citizens have confidence in and abide by laws) (Kaufmann and Kraay 2017).

When necessary, we impute missing values of the selected indicators to balance sample sizes across countries and maximize the number of countries in the sample. We use different methods depending on the number of available data and the characteristics of the indicators. For a country that has data for more than 10 out of 30 years (1985–2014) for an indicator, we project a linear trend over years to impute missing values. For a country that has data for less than 10 years, we replace missing values with a median value corresponding to the country's income and regional group. We apply a different method for PISA scores because available data are less than for 10 years for all countries. Considering a statistically significant correlation of 0.66 (p-value<0.01) between PISA scores and log-transformed GDP per capita lagged by five years, we regress PISA scores on the lagged log–transformed GDP per capita, controlling for time-effects in a cross-country, time-series pooled data set.[6] Then, we replace missing PISA scores with a median score by the country's income and regional group using scores predicted by the regression model. For minimum wage and severance pay, we apply the oldest available data (2014) to the period before 2014, because available data (2014–2017) are insufficient to evaluate a time trend, and their values are difficult to impute based on the country's income and regional group.

[6] $PISA_{c,t} = \beta_0 + \beta_1 \ ln\ (GDP\ per\ capita)_{c,t-5} + \delta_t$, *c:country* (1,…,76), *t: year* (2003/06/09/12/15); β_0 = 187.1*, $\beta 1$ = 28.7 *** (***: p-value<0.01), R^2=0.444.

3.4 Relationship between the main determinants of TFP and TFP growth

The relative contribution of the main determinants to the variance of total factor productivity growth

To help assess the relative contribution of the five main determinants to TFP growth, we decompose the variance of the TFP growth rate (over t-5 to t) to that explained by each subcomponent index (at t-5), controlling for an initial TFP level (at t-5) and time-effects for 98 countries. A review of measures of relative importance based on variance decomposition by Grömping (2007) suggests that the "dominance analysis" approach (Budescu 1993; Azen and Budescu 2003) is a reasonable method, mainly to deal with the presence of covariance across individual determinants. This approach calculates the contribution of a subcomponent index as the increase in the explained variance when the subcomponent index is added to each subset of other subcomponent indexes. For instance, the contribution of the innovation index ($innov_{c,t}$) is computed by averaging[7] the increase in the explained variance of TFP growth rate when $innov_{c,t}$ is added to each of the 16 additive subsets of other four subcomponent indexes ({.}, {$educ_{c,t}$}, …, {$inst_{c,t}$}, { $educ_{c,t}$, $effi_{c,t}$}, … {$infra_{c,t}$, $inst_{c,t}$}, {$educ_{c,t}$, $effi_{c,t}$, $infra_{c,t}$}, …, {$educ_{c,t}$, $infra_{c,t}$, $inst_{c,t}$}, {$educ_{c,t}$, $effi_{c,t}$, $infra_{c,t}$, $inst_{c,t}$}.)

The relationship between the overall determinant index and total factor productivity growth

To quantify the relationship between the overall determinant index and TFP growth, we build a regression model in which TFP growth rate is a function of a time-lagged overall determinant index and a time-lagged TFP level with country- and time-effects (equation (2)). We rescale the overall index to be from 1, representing the lowest performance, to 100, the best across countries over the last three decades. For this purpose, we use the following linear transformation, (*original index for country c and time t − lowest index*)/(*highest index − lowest index*)*(100−1)+1. According to preliminary analysis, the relationship between the index and TFP growth declines as the index increases; to allow for this non-linearity, we log-transform the rescaled index. We apply a time lag of five years to reduce the likelihood of endogeneity as reverse causation. This also allows us to smooth the TFP growth series, considering that, at shorter frequencies, it may be driven by business-cycle fluctuations (see Beck, Levine, and Loayza 2000; and Giavazzi and Tabellini 2005).

We run different regressions for comparison and robustness check: without country-effects and with random country-effects, and with different time lags of three and seven years. We use (White-Huber) robust standard errors. After fitting the models to the sample, we incorporate the results into the Long Term Growth Model (Loayza and Pennings 2018) in order to run country and region simulations on the potential path of TFP growth.

$$Annualized\ TFP\ growth_{c,(t,t-5)} = \beta_0 + \beta_1\, ln\,(Index_{c,t-5}) + \beta_2\, ln\,(rtfpna)_{c,t-5} + \theta_c + \delta_t + \varepsilon_{c,t}. \quad (2)$$

$Annualized\ TFP\ growth_{c,(t,t-5)}$: annualized TFP growth over t−5 and t

$Index_{c,t-5}$: overall determinant index, rescaled 1 to 100

$rtfpna_{c,t-5}$: *TFP level* (2011 = 1)

θ_c: country effect

δ_t: time effect

$\varepsilon_{c,t}$: residuals

[7] Two-step average: First, the additional contributions are averaged within a group of the same size of the subset, then the results from the first step are averaged across groups with different sizes of the subset.

4. Results

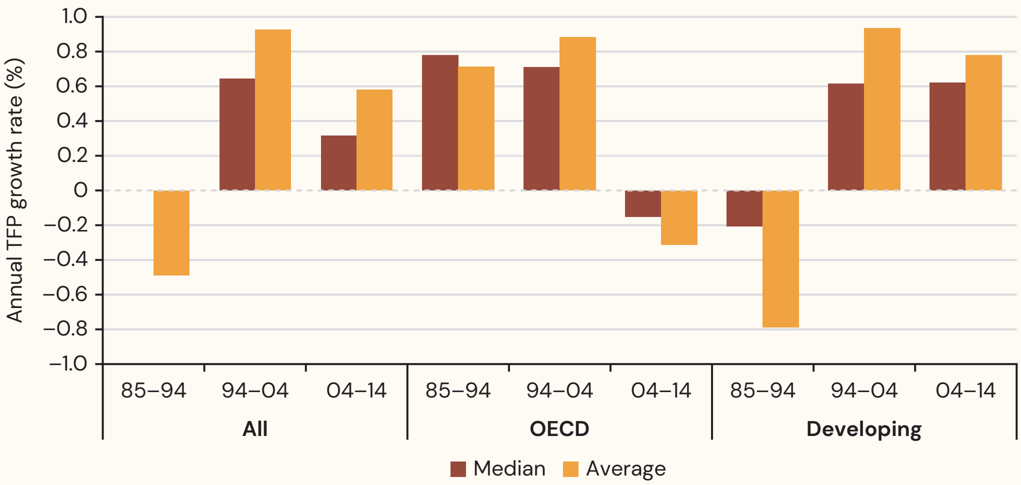
4.1 Total factor productivity

Figure 3.2 shows that for 21 OECD countries, the median and (simple) average annual TFP growth rates are positive during 1985–2004 and decrease below zero for 2005–2014; whereas for 93 developing countries, they are negative during 1985–94 and increase above zero for 1995–2014. Figure 3.3 shows median and (simple) average annual TFP growth rates for developing countries by region. For East Asia and Pacific, TFP growth rates are positive for the last three decades between 0.4 percent and 1.3 percent. For Europe and Central Asia, TFP growth rates are negative for 1985–1994, increase in the next decade to above 2.0 percent, and decrease to around 1.2 percent for the last decade. For Latin America and the Caribbean, TFP growth rates increase from around –0.4 percent during 1985–2004 to around 0.5 percent for 2005–2014. For Middle East and North Africa, TFP growth rates increase from near zero or negative in 1985–94 to around 0.5 percent in the next decade and decrease to below –0.5 percent in the last decade. For South Asia, TFP growth rates are positive for the last three decades, ranging between 0.3 percent and 1.5 percent. For Sub-Saharan Africa, TFP growth rates increase from around –1 in 1985–1994 to +1 in the two decades spanning 1994–2014. Figure 3.4 shows regional average TFP growth rates weighted by total GDP (World Bank 2017d), the trend of which is similar to that of the unweighted average TFP growth rates in figure 3.3.

4.2 Main determinant indexes

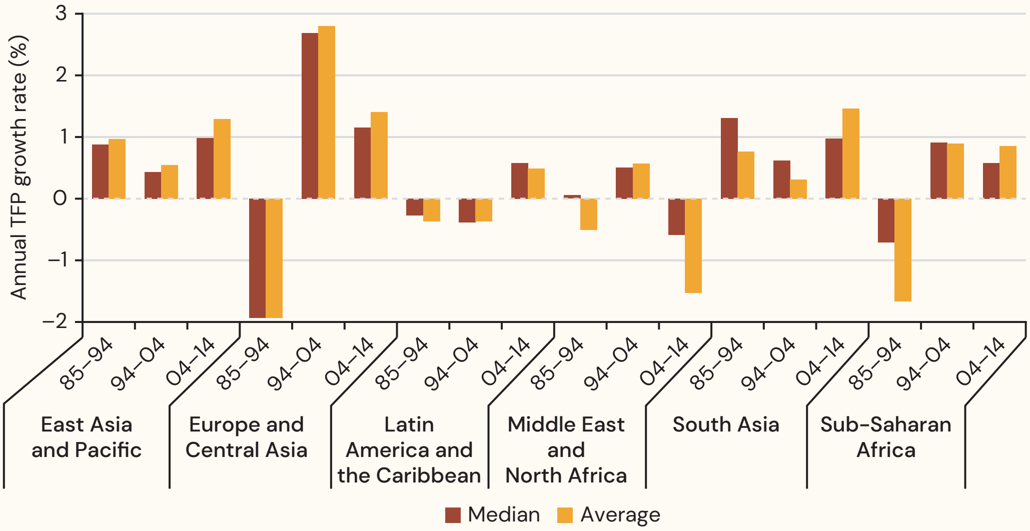
Figure 3.5 shows the median of the subcomponent indexes representing the main categories of TFP determinants, as well as the median of the overall index, for all, 21 OECD, and 115 developing countries by decade. All the median indexes are lower for the developing countries as compared to the OECD countries. A noticeable difference is that the innovation index stays at the lowest level for the developing countries, whereas it increases in the OECD group over time. For both groups, the subcomponent indexes of education, market efficiency, and infrastructure increase over decades, whereas that of institutions stays at the same level.

Figure 3.2: Annual TFP Growth Rate for All, OECD, and Developing Countries, Median and Simple Average by Decade



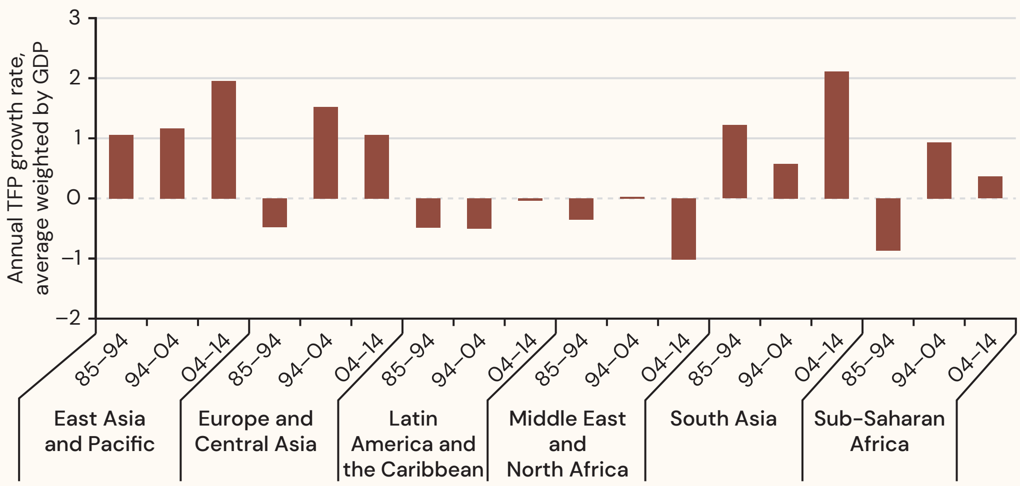
Source: Authors' calculation, using PWT 9.0 data complemented, in a few cases, with GTAP data.
Note: The OECD group includes high-income countries that have been members of OECD for more than 40 years; the former Soviet Union countries are excluded in the period 1985–1994 considering their independence in the early 1990s.

Figure 3.3: Annual TFP Growth Rate for Developing Countries, Median and Simple Average by Region and Decade



Source: Authors' calculation, using PWT 9.0 data complemented, in a few cases, with GTAP data.
Note: The former Soviet Union countries are excluded in the period 1985-94 considering their independence in the early 1990s.

Figure 3.4: Annual TFP Growth Rate for Developing Countries, Average Weighted by Real GDP by Region and Decade

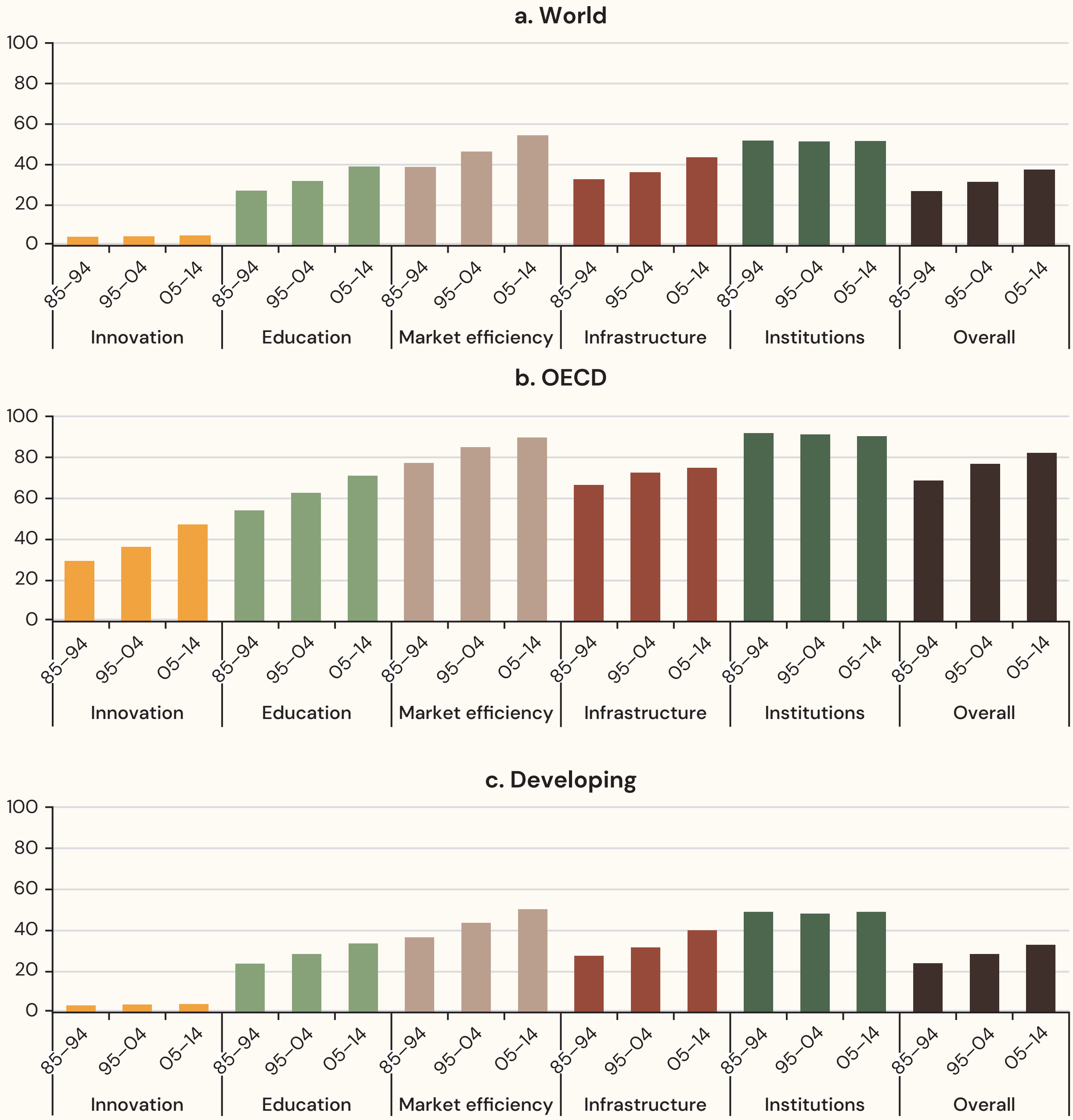


Source: Authors' calculation, using PWT 9.0 data complemented, in a few cases, with GTAP data.
Note: The former Soviet Union countries are excluded in the period 1985-94 considering their independence in the early 1990s.

For the innovation subcomponent index, the indicators carry similar weights (equation 3). A factor analysis shows that the subcomponent index accounts for 76 percent of the total variance of the indicators, accounting for 90 percent of the variance of R&D expenditure (*R&D*), 61 percent of that of the number of patents (*patent*), and 79 percent of that of the number of journal articles (*article*).

$$Innov_{c,t} = 0.41 * z\,(R\&D_{c,t}) + 0.34 * z\,(patent_{c,t}) + 0.39 * z\,(article_{c,t}), \tag{3}$$

Figure 3.5: Median of Subcomponent and Overall Determinant Indexes for All, OECD, and Developing Countries by Decade



Source: Authors' calculation.
Note: The OECD group includes high-income countries that have been members of OECD for more than 40 years; the indexes are rescaled to range from 1, the lowest performance, to 100, the best among all countries over the three decades.

where $z(X)$ *is standardized* X, $\frac{X - \text{mean}(X)}{\textit{standard deviation }(X)}$.

For the education subcomponent index, the performance-related indicators have similar weights and the education-expenditure indicator has a lower weight (equation 4). A factor analysis indicates that the sub-component index accounts for 55 percent of the total variance in the indicators, accounting for 20 percent of the variance of education expenditure (*eduexp*), 63 percent of that of secondary attainment (*secondary*), 75 percent of that of tertiary attainment, and 63 percent of that of PISA scores (*pisa*). The lower weight and the smaller contribution of the education expenditure indicator to the common variance shows that this indicator has a low correlation with the outcome indicators.

$$Edu_{c,t} = 0.20 * z(eduexp_{c,t}) + 0.36 * z(secondary_{c,t}) + 0.39 * z(pisa_{c,t}) + 0.36 * z(tertiary_{c,t}). \quad (4)$$

For the market efficiency subcomponent index, the indicators are combined with similar weights (in absolute terms) (equation 5). A factor analysis shows that the subcomponent index accounts for 69 percent of the total variance in the three indicators, accounting for 79 percent of the variance of Doing Business scores (*business*), 78 percent of that of Financial Development Index (*financial*), and 49 percent of the labor index (*labor*). In turn, a factor analysis shows that the labor index accounts for 48 percent of the total variance of the minimum wage (*minwage*), 53 percent of that of the severance pay (*severance*), and 52 percent of that of the share of women employed in the nonagricultural sector (*women*).

$$Effi_{c,t} = 0.43 * z(business_{c,t}) + 0.43 * z(financial_{c,t}) - 0.34 * z(labor_{c,t}), \quad (5)$$

$$\text{where } labor_{c,t} = 0.45 * z(minwage_{c,t}) + 0.47 * z(severance_{c,t}) - 0.47 * z(women_{c,t})$$

For the infrastructure subcomponent index, all indicators except for mobile subscription have similar weights (equation 6). A factor analysis shows that the subcomponent index accounts for 65 percent of the total variance in its indicators, accounting for 78 percent of the variance of the number of telephone subscription (*tele*), 28 percent of that of mobile subscription (*mobile*), 64 percent of that of paved road (*road*), 67 percent of that of electricity production (*elec*), 70 percent of that of access to improved water source (*water*), and 76 percent of that of access to improved sanitation facilities (*sanit*).

$$Infra_{c,t} = 0.23 * z(tele_{c,t}) + 0.14 * z(mobile_{c,t}) + 0.21 * z(road_{c,t}) + 0.21 * z(elec\_(c,t)) + 0.22 * z(water_{c,t}) + 0.23 * z(sanit_{c,t}). \quad (6)$$

The institutions subcomponent index consists of the six indicators with similar weights (equation 7). The subcomponent index accounts for 87 percent of the total variance in its indicators, accounting for 83 percent of the variance of voice and accountability (*va*), 90 percent of that of the control of corruption (*cc*), 93 percent of that of government effectiveness (*ge*), 71 percent of that of political stability (*ps*), 89 percent of that of regulatory quality (*rq*), and 94 percent of that of the rule of law (*rl*).

$$Inst_{c,t} = 0.18 * z(va_{c,t}) + 0.19 * z(cc_{c,t}) + 0.19 * z(ge_{c,t}) + 0.16 * z(ps_{c,t}) + 0.18 * z(rq_{c,t}) + 0.19 * z(rl_{c,t}). \quad (7)$$

The overall determinant index is a linear combination of the (standardized) five subcomponent indexes with similar weights (equation 8). The overall index, obtained through a principal component analysis, represents the innovation index with a correlation of 0.88; the education index, 0.90; the market efficiency index, 0.94; the infrastructure index, 0.94; and the institutions index, 0.87.

$$Index_{c,t} = 0.43 * z(Innov_{c,t}) + 0.44 * z(Edu_{c,t}) + 0.46 * z(Effi_{c,t}) + 0.47 * z(Infra_{c,t}) + 0.43 * z(Inst_{c,t}). \quad (8)$$

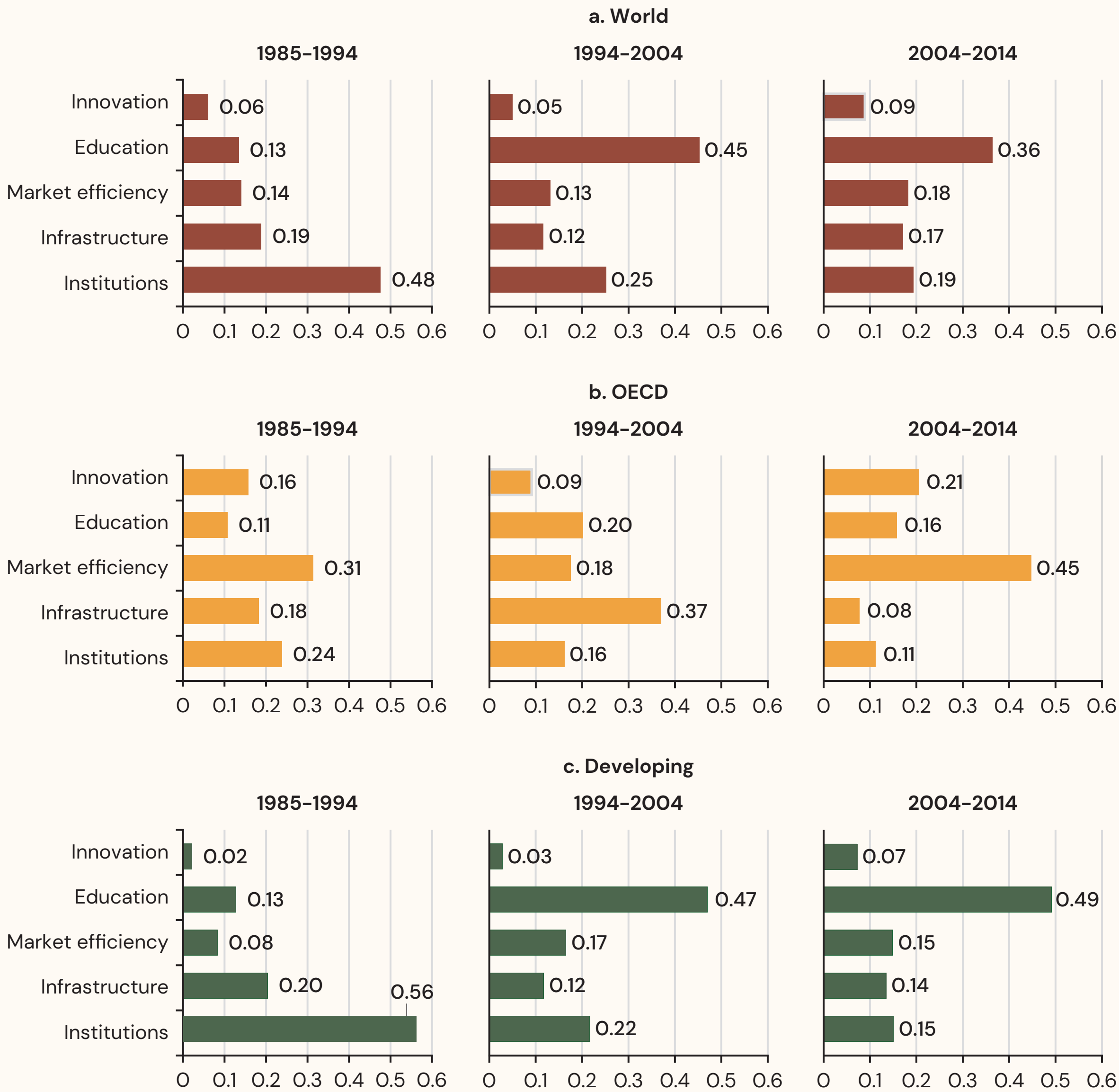
Appendix C shows the average values of the individual indicators, as well as the subcomponent and overall indexes, over 1985–2014 by income and regional group.

4.3 Relationship between the main determinants of TFP and TFP growth

The relative contribution of the main determinants to the variance of total factor productivity growth

Figure 3.6 shows the decomposition of the total explained variance of the TFP growth rate corresponding to each of the main TFP determinants by decade for all, OECD, and developing countries (controlling for the five-year-lagged TFP level and time-effects). For the OECD countries, a notable trend is that the contribution of the market efficiency index increases and accounts for 45 percent of the explained variance of TFP growth in the last decade; whereas that of infrastructure decreases and explains the least. For developing countries, in 1985–1994 the TFP determinant with the highest explanatory power of TFP growth variance is

Figure 3.6: Variance Decomposition of TFP Growth Rate Corresponding to the Determinant Subcomponent Indexes (by decade for all, OECD, and developing countries, controlling for initial TFP and time effects)



Source: Authors' calculation.
Note: The OECD group includes high-income countries that have been members of OECD for more than 40 years.

institutions; however, its contribution decreases afterward. The contribution of education increases over the two decades and accounts for almost 50 percent of the explained variance of TFP growth in the last decade.

The variance decomposition analysis helps understand what drives the differences across countries regarding TFP growth. It does not, however, indicate what the most important or relevant drivers of TFP growth are for specific countries. For this, we would need to know the country-specific gaps in each determinant of TFP. We turn to this issue in section 6, on simulations and scenario analysis. Before, however, we need to obtain a reasonable estimate of the effect of the overall index on TFP growth, which we attempt next.

The relationship between the overall determinant index and total factor productivity growth

Table 3.1 shows the regression results for equation 2 in which the TFP growth rate is a function of the lagged overall determinant index and the lagged TFP level, along with country- and time-effects. We do not attempt a regression with the five subcomponent indexes as individual regressors because they are very highly correlated, and their estimated marginal effects would be contaminated by multicollinearity.

As table 3.1 shows, the lagged overall index and the lagged TFP level are statistically significant in all regressions, with no, random, and fixed country-specific effects, respectively. Based on the Hausman test, which suggests bias estimation if correlated country-specific effects are not considered, we choose to focus on the regression with fixed (correlated, not random) country-specific effects.

Table 3.1: Linear Regression Results

Dependent variable	*Annualized TFP growth*$_{c,(t-5,t)}$		
Number of observations	**477**		
Number of groups (countries)	**98**		
	Country effects:		
	None	**Random**	**Fixed**
Regressors (below)	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**
$ln(Index_{c,t-5})$	0.004 (0.0011) ***	0.004 (0.0011) ***	0.050 (0.0183) ***
$ln(TFP\ level)_{c,t-5}$	–0.082 (0.0052) ***	–0.082 (0.0052) ***	–0.099 (0.0151) ***
Year 1999	–0.001 (0.0036)	–0.001 (0.0036)	-0.006 (0.0034)
Year 2004	0.012 (0.0031) ***	0.012 (0.0031) ***	0.004 (0.0034)
Year 2009	0.010 (0.0030) ***	0.010 (0.0030) ***	–0.001 (0.0045)
Year 2014	0.010 (0.0034) ***	0.010 (0.0034) ***	–0.004 (0.0063)
(Reference year: 1993)			
Constant	–0.021 (0.0055) **	–0.021 (0.0055) ***	–0.180 (0.0636) ***
R^2:			
Within	Not applicable	0.2784	0.3048
Between	Not applicable	0.8573	0.2749
Overall	0.4022	0.4022	0.1586

Note: SE = Standard error; * = significant at 10%; ** = significant at 5%; *** = significant at 1% level.
Hausman test rejects the null hypothesis (Ho: coefficients are consistent under both random and fixed effects) with Chi-square 22.90 and p-value less than 0.01. The R^2 in the case of the fixed-effects estimator does not consider the explanatory contribution of the country-specific constants (which is why its overall value is lower than in the other cases). In the regression with no country effects, we use clustered robust (White-Huber) variance estimation, treating countries as clusters.

In the fixed effects model, an increase of the lagged overall determinant index by 1.00 percent is associated with an increase of the annual TFP growth rate by 0.05 percent, after controlling for the lagged TFP level and country and time effects. Suggesting convergence, an increase of lagged TFP by 1.00 percent is associated with a decrease of annual TFP growth rate by 0.10 percent, holding other variables constant. This implies that countries with a higher level of TFP need to increase the determinant index more than those with a lower level of TFP to achieve the same amount of increase in TFP growth. These results are robust in terms of signs and significance when we use different lags of three and seven years (see appendix D). They are also robust when we use the WDI-based data in the construction of TFP levels and growth rates (see appendix E).

5. Simulations and Scenario Analysis

5.1 Groups of countries by geographic region and income level

For illustration purposes, in this section we simulate the change in TFP growth rate for 78 low- and middle-income developing countries (that is, countries with GDP per capita in 2014 lower than US$12,056, constant USD 2010). We present the simulation results in averages by region or income group. More generally, the Long Term Growth Model (LTGM) toolkit can be used to generate country-specific projections for TFP growth for a much larger set of countries. This allows the LTGM users to replace the assumption of an exogeneous path for TFP growth by one that is based on improvements in innovation, education, market efficiency, infrastructure, and institutions, feeding into the overall determinant index.

We provide four scenarios below. They present different ways and extents of improving the TFP determinant index to regional or world benchmarks (or leaders). We use the fixed-effect regression results to relate changes in TFP growth to changes in the overall determinant index. The corresponding increase in TFP growth depends directly on the speed of progress in the country's TFP determinants and inversely on the extent of previous TFP improvement. Thus, countries with a larger gap on their TFP determinant index with respect to the benchmark could experience a larger increase in TFP growth if they made reforms to approach the leader. In turn, countries with a high increase in TFP growth would slow down their subsequent growth in TFP. The positive impact of improvements in the TFP determinant index and the negative impact of previous TFP growth create an interesting, nonlinear path of projected TFP growth. In most cases, TFP growth follows a convex path that increases at a decreasing rate, reaches a maximum, and then decreases or stabilizes. Since in the simulations the reforms to improve TFP determinants do not occur immediately but gradually over time (in two scenarios, to imitate the actual trajectory of benchmark countries in the last three decades), the projected TFP growth has an additional source of convexity, as the growth rate of the TFP determinant index tends to decline over time.

Scenario I: Improving to the highest TFP determinant index in the region

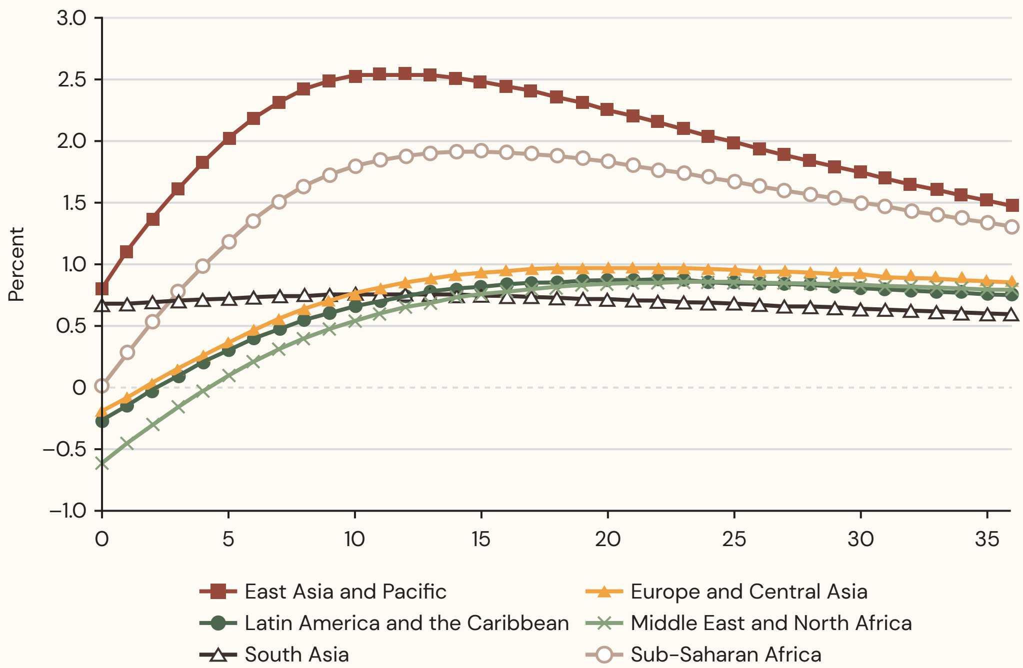
Scenario I assumes that a country improves its overall determinant index to the highest index among all developing (non-OECD) countries in its region. We assume a country's overall determinant index increases at constant increments from the initial value (in 2014) to the current index of its benchmark country, shown in table 3.2, over 15 years and keeps increasing with the same slope afterward.

Figure 3.7 shows the average TFP growth rate under scenario I. For East Asia and Pacific, starting from the highest historical average TFP growth rate over 1985–2014 among all regions, the average TFP growth rate is expected to increase to 2.5 percent over the next 12 years and then gradually decrease. For Sub-Saharan Africa, the average TFP growth is expected to increase to 1.9 percent over the next 15 years, which is the sharpest increase from the corresponding historical TFP growth rate among all regions. For Europe and Central Asia, Latin America and the Caribbean, and Middle East and North Africa, the simulated average TFP growth rates are similar in that they increase to almost 1.0 percent in the next 23 years and

Table 3.2: Benchmark Countries with the Highest Overall Determinant Index as of 2014 by Region

Region	Country with the highest index as of 2014
East Asia and Pacific	Korea, Rep.
Europe and Central Asia	Czech Republic
Latin America and the Caribbean	Chile
Middle East and North Africa	United Arab Emirates
South Asia	India
Sub-Saharan Africa	South Africa

Figure 3.7: Simulated Average TFP Growth rate by Region (with the scenario that a country increases its overall determinant index to the highest index among developing countries in its region over 15 years)



decrease gradually. For South Asia, the average TFP growth rate stays in the range from 0.6 to 0.8 percent. Using regional benchmarks limits the possibility of progress in TFP growth because the regional leaders may not be very advanced themselves. Such is the case of India for South Asia.

Scenario II: Following the trajectory of the most improving TFP overall index in the region

Scenario II assumes that a country replicates the trajectory, in terms of annual change, in the last three decades of the TFP overall determinant index corresponding to the regional benchmark country. The regional benchmark under scenario II is the country whose overall determinant index increases the most over 1985–2014 among all developing (non-OECD) countries in a given region (see table 3.3).

We apply the annual change in the index of the benchmark country over 1985–2014 to that of all countries in the same region, starting from the initial index (2014) for the next 30 years and the average change over 2005–2014 for subsequent years.

Figure 3.8 shows the predicted average TFP growth rate under scenario II. For East Asia and Pacific, starting from the highest historical average TFP growth rate over 1985–2014, the average TFP growth rate is expected to increase to 1.7 percent over the next 15 years and then decrease. For Latin America and the Caribbean and Sub-Saharan Africa, the simulated average TFP growth rate increases for more than 30 years to 0.9 and 1.2 percent, respectively. For Europe and Central Asia and Middle East and North Africa, the average TFP growth rate is expected to increase to 0.7 and 0.6 percent, respectively, over the next 20 years and decrease gradually. For South Asia, the simulated TFP growth rate stays in the range from 0.6 to 0.9 percent.

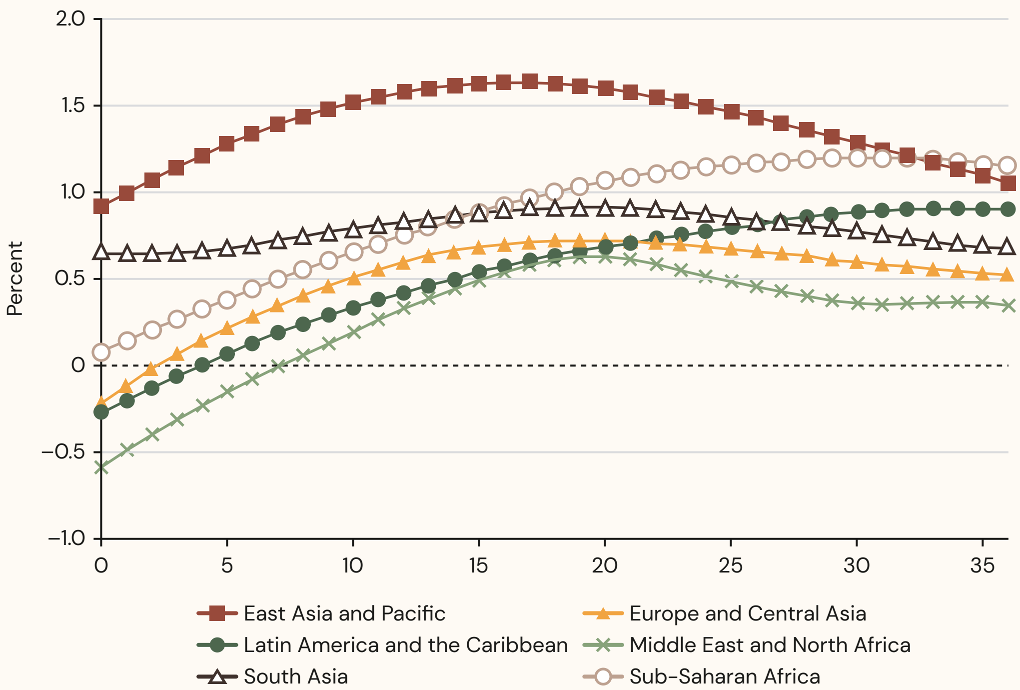
Scenario III: Improving to the highest TFP determinant index among all developing countries

Scenario III assumes that a developing country increases its overall determinant index to the highest index among all developing (non-OECD) countries as of 2014, which is that of the Republic of Korea.

Table 3.3: Benchmark Countries with the Most Increase in the Overall Determinant Index during 1985–2014 by Region

Region	Country with the most increase in the overall index during 1985–2014
East Asia and Pacific	Korea, Rep.
Europe and Central Asia	Czech Republic
Latin America and the Caribbean	Colombia
Middle East and North Africa	United Arab Emirates
South Asia	India
Sub-Saharan Africa	Rwanda

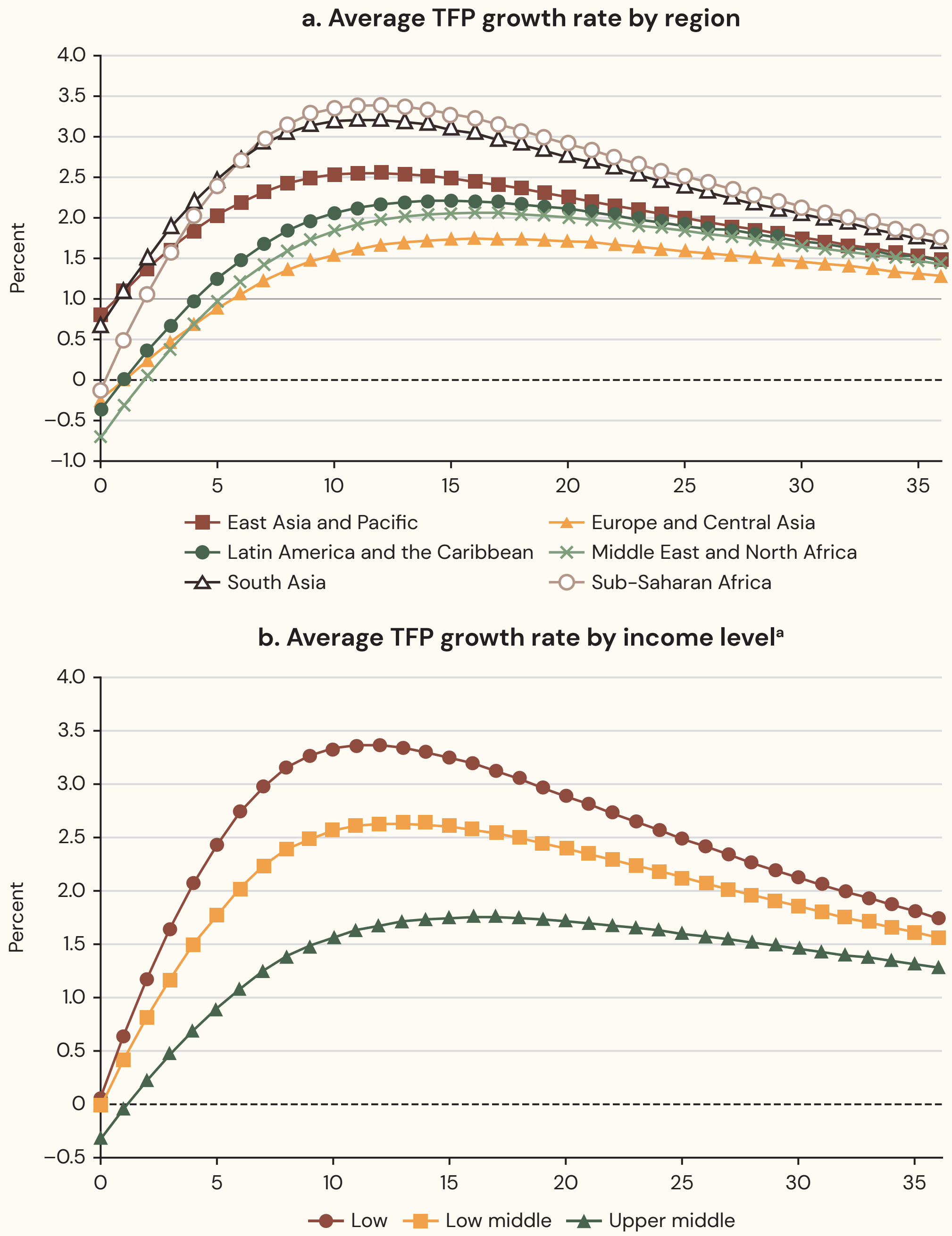
Figure 3.8: Simulated Average TFP Growth Rate by Region (with the scenario that a country replicates the annual index change that its benchmark country has had in the last three decades)



We assume a country's overall determinant index increases linearly from the value in 2014 to the index of Korea over 15 years and keeps increasing with the same slope afterward.

Figure 3.9a shows that Sub-Saharan Africa, which has the largest gap with respect to the benchmark and has a relatively low TFP growth rate, is expected to have the highest increase from its historical average over 1985–2014 (initial value in the graph) and reach the highest average TFP growth rate of 3.4 percent in 11 years and then gradually decline. South Asia is expected to increase its TFP growth rate to 3.2 percent in 11

Figure 3.9: Simulated Average TFP Growth Rate by Region and Income Group (with the scenario that a country increases its overall determinant index to the highest index among developing countries over 15 years)



[a] Low: average GDP per capita over 1985–2014 (constant 2010 USD) ™$995; Low middle: $995-$3,895; Upper middle: $3,895-$12,055.

years and then decrease, similarly to Sub-Saharan Africa. East Asia and Pacific, with the highest historical average, is expected to increase its average TFP growth rate to 2.5 percent in 11 years; this is smallest gain from the historical average among all regions, reflecting its already high TFP growth in the past. Latin America and the Caribbean, and Middle East and North Africa, with negative historical average TFP growth, are expected to increase the average TFP growth rate to 2.2 and 2.1 percent, respectively, in 15 years. For Europe and Central Asia, with a negative historical growth, the average TFP growth rate increases to 1.7 percent in 16 years and then decreases.

Grouping countries by income level reveals interesting patterns. Figure 3.9b shows that the low-income group is expected to increase its average TFP growth rate the most to 3.3 percent in 11 years, the low-middle-income group to 2.6 percent in 12 years, and the upper-middle-income group to 1.8 percent in 16 years. In all cases, TFP growth gradually declines after reaching a peak, approaching around 1.5 percent in 35 years. These results confirm the notion obtained from the regional results: a country, region, or group with a larger gap in the TFP determinant index with respect to the benchmark has more to gain and can experience a substantial increase in TFP growth if they conduct the corresponding reforms. For those with already high TFP growth and for those whose TFP growth rises sufficiently, subsequent TFP growth will tend to taper down.

Scenario IV: Following the trajectory of the most improving TFP overall index among all developing countries

Scenario IV assumes that a country replicates a trajectory, in terms of annual change, of the world benchmark country. This is the country that has increased its overall determinant index the most over 1985–2014 among all developing (non-OECD) countries, which is Korea. We apply the annual change in the index of Korea over 1985–2014 to that of a country starting from the initial index (2014) for the next 30 years and the average change over 2005–2014 for subsequent years.

Figure 3.10a shows that Sub-Saharan Africa, with the largest gap with respect to the benchmark and a relatively low TFP growth rate, has the highest increase from its historical average over 1985–2014 (initial value in the graph) and reaches the highest average TFP growth rate of 2.1 percent in 16 years. South Asia is expected to increase its TFP growth rate to 2.0 percent in 16 years and decrease afterwards. East Asia and Pacific, with the highest historical average TFP growth, has the smallest projected increase in TFP growth, to 1.7 percent in 15 years. Latin America and the Caribbean, Middle East and North Africa, and Europe and Central Asia, with negative historical average TFP growth, are expected to increase their TFP growth rates to 1.2 to 1.4 percent in 19–20 years.

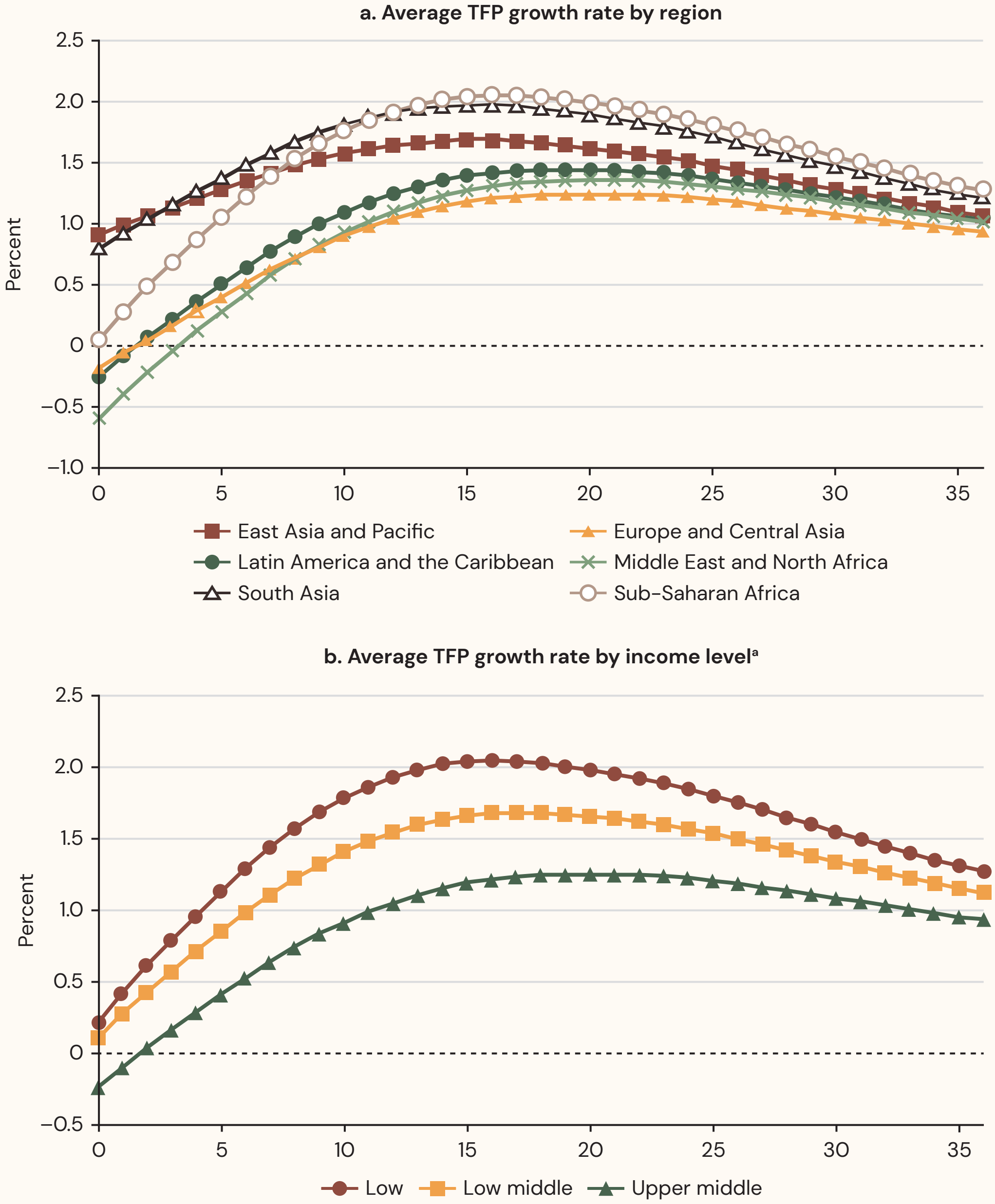
Figure 3.10b presents the results for income groups. It shows that the low-income group is expected to increase its average TFP growth rate the most to 2.0 percent in 16 years, the low-middle income group to 1.7 percent in 17 years, and the upper-middle-income group to 1.2 percent in 20 years. The results in figure 3.10 confirm the insight that countries, regions, or groups with a larger gap with respect to the benchmark, such as Sub-Saharan Africa, have more to gain in terms of future TFP growth, and those with higher TFP growth, for example, East Asia and Pacific, have a slower subsequent TFP growth.

5.2 Peru: Country-specific illustration

As mentioned before, the productivity component of the LTGM toolkit allows for a multitude of scenarios on the future path of TFP growth for individual countries. In this chapter, as an illustration, we present three sets of scenarios for Peru. They are shown in figure 3.11. In each case, we postulate a given path for the overall TFP determinant index from the present to the year 2050 (left panels) and then obtain the corresponding path for TFP growth for the same period (right panels).

An important element in all scenarios is the historical level of TFP growth, which drives not only the initial position of TFP growth but also how difficult it is to increase TFP growth further in the future (with higher

Figure 3.10: Simulated Average TFP Growth Rate by Region and Income Group (with the scenario that a country replicates the trajectory of the overall index of Korea, which increases the index the most among all developing countries in the last three decades)

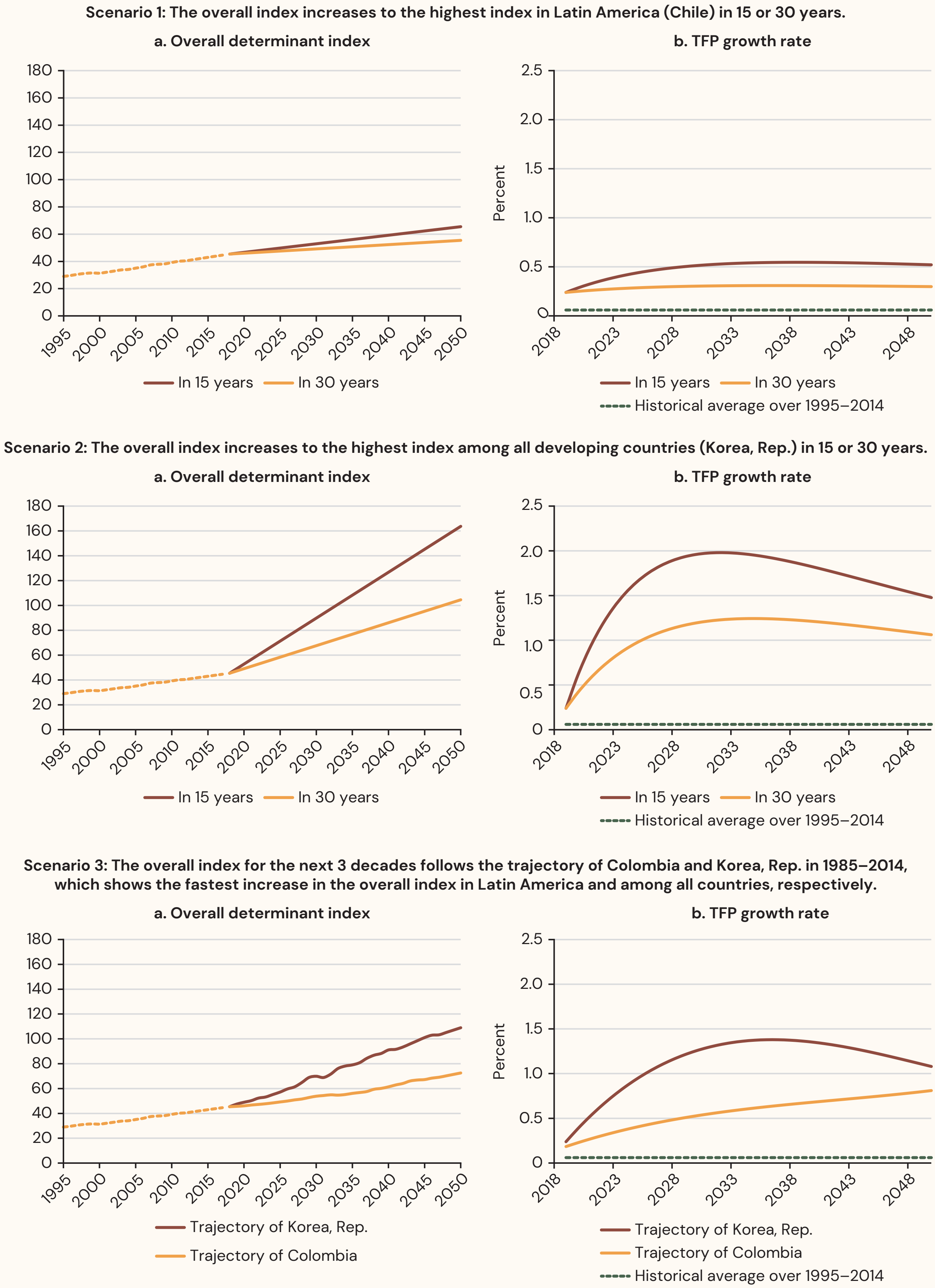


[a] Low: average GDP per capita over 1985-2014 (constant 2010 USD) TM$995; Low middle: $995-$3,895; Upper middle: $3,895-$12,055.

rates being harder to improve). In the case of Peru, we choose the historical level of TFP growth to be equal to the average for the two most recent decades for which we have data, 1995–2014. This avoids the macroeconomic and social crisis (recession, hyperinflation, civil conflict, and recovery) of the 1980s and early 1990s. Similar analyses and choices can be made for each country whose future TFP growth is to be simulated.

In scenario 1, the overall TFP determinant index in Peru is assumed to reach the highest current index in Latin America, which corresponds to Chile, in either 15 years (dark-red line) or 30 years (orange line). The target rate of improvement is modest, and, correspondingly, the productivity gains are low. Reaching Chile's current index in 30 years brings no gain in TFP growth and reaching it in 15 years allows to obtain

Figure 3.11: Projected TFP Growth Rates for Peru under Various Scenarios



a TFP growth of 0.5 percent. The latter, modest gain, is consistent with a continuation in the rate of improvement in the TFP determinant index that Peru has experienced since the mid-1990s.

Peru's development aspirations demand a larger rate of economic growth, and this, in turn, requires a faster TFP growth rate. This can be achieved only if the pace of reforms to improve the determinants of TFP increases substantially. Scenarios 2 and 3 consider two such alternatives.

In scenario 2, the overall TFP determinant index in Peru is assumed to reach the highest index among all developing countries (to be more precise, among all countries not belonging to the OECD for at least 40 years). This country is Korea. As in scenario 1, we consider two cases, reaching Korea's level in 15 years (dark-red line) or 30 years (orange line). Both represent a departure from the previous trend, especially, of course, the target of achieving Korea's current TFP index in 15 years. The gains in TFP growth are correspondingly large: focusing on the fast improvement case, TFP growth rises from nearly 0 percent to 1.5 percent in five years, reaches 2.0 percent in twelve years, and then tapers down to about 1.5 percent by 2050. To be possible, this scenario would represent a radical improvement of sustained and, for Peru's standards, high TFP growth. But is this target unrealistic? Scenario 3 presents a less ambitious and arguably more realistic case.

In scenario 3, the overall TFP determinant index in Peru is assumed to mimic the changes observed in the index of the most improving countries in Latin American and in the world in the last three decades for which we have data, 1985–2014, and then continue with the same trend. These countries are, respectively, Colombia (orange line) and Korea (dark-red line). Imitating the Colombian improvement would render some gains for TFP growth, sustained but slow, approaching 1.0 percent by 2050. However, this is hardly what Peru needs to boost long-run economic growth. Imitating the Korean improvement is more promising and, of course, more demanding. It would allow Peru to raise its TFP growth from nearly 0 percent to 1.0 percent in seven years, reach almost 1.5 percent in about fifteen years, and then reduce gradually to over 1.0 percent by 2050.

For Peru, as for most countries around the world, sustained TFP growth is essential for economic growth. By itself, however, it cannot support an ambitious growth target. It must be accompanied by a strong effort in physical capital accumulation, labor force participation, and quality, as well as the required domestic savings.

6. Conclusion

This is the background chapter for the TFP extension of the World Bank's Long Term Growth Model (LTGM) that was presented in chapter 1. It proposes a way to project the future path of TFP growth for most developing countries around the world if they were to follow a program of reforms that would approach them to regional and global leaders. The chapter is accompanied by an Excel-based toolkit, which can be used for scenario analysis on TFP and corresponding income growth (available at the LTGM's website: https://www.worldbank.org/LTGM).

Based on a comprehensive literature review, we select innovation, education, market efficiency, infrastructure, and institutions as the five main categories of TFP determinants. For each of these categories, we construct an index as a linear combination of representative indicators (or proxies) by a factor analysis, that is, by accounting for as much of the common variance in the indicators as possible. We then combine the five subcomponent indexes into an overall index by the principal component analysis, which accounts for as much of the total variance in the subcomponent indexes as possible.

Using dominance analysis, the variance decomposition of the TFP growth rate into the main subcomponent indexes shows that for OECD countries, market efficiency contributes the most to the variance of TFP growth and infrastructure, the least for the recent decade; and for developing countries, the contribution of education increases continuously and is the largest among the determinants in the recent decade. Although the variance decomposition of TFP into its determinants is not necessarily a guide for policy reform, it illustrates how the observed variation in TFP growth can be explained differentially over time and across development levels. This suggests patterns that countries can use to assess their own progress in the various determinants of productivity.

On its part, regression analysis shows that an increase in the overall determinant index is significantly associated with an increase in the TFP growth rate, controlling for the initial TFP level and country- and time-effects. Countries that have a larger room for improvement in the determinants of TFP and make a stronger effort of reform would experience a larger increase in TFP growth, which is expected to rise over time and then taper down. The slowdown of TFP growth in the long run is explained by the increasing difficulty of expanding TFP when its level is higher (given the estimated negative regression coefficient on past TFP) and the deceleration (in proportional terms) in the TFP determinant index itself.

Though significant and reasonable by historical standards, the increase in TFP growth is projected to be between 2.5–3.0 percentage points in the best cases of substantial reform, not enough by itself to support overly ambitious economic growth targets. Alongside productivity improvements, savings, investment, labor participation, and human capital formation should continue to figure prominently in countries' growth and development agendas.

This study has some limitations that should be considered when interpreting the results. One limitation is that the TFP determinants could be endogenous in relation to TFP growth. To mitigate this risk, we use lagged observations of the TFP determinant index in the variance decomposition and regression analyses. This may be a more straightforward and less biased approach than using instrumental variables that could be questionable (see Young 2017). Another limitation is that we do not include all possible determinants of productivity, either as broad categories or specific indicators. For instance, we do not directly include geographic conditions, workforce demographics, income and wealth inequality, or firm-specific entrepreneurship, and managerial ability (Feyrer 2007; Mastromarco and Zago 2012; Kremer, Rao, and Schilbach 2019). We attenuate the potential problem by including country-specific effects, a reasonable strategy to control for productivity determinants that are persistent over time. Also, we include a number of indicators that represent not only their limited definition but also proxy for a wider array of variables not represented in our measurements. A third limitation deals with the well-known drawbacks of measuring productivity as a residual. In a sense, the Solow residual is a "measure of our ignorance" (Abramovitz 1956), capturing not only productivity proper but also a variety of factors, from excess capacity and natural resources to heterogeneous and intangible capital (Hulten 2001; Corrado, Hulten, and Sichel 2009). Nevertheless, we believe that focusing on average growth rates of TFP over several years (rather than on TFP levels or high-frequency TFP growth) is conducive to reducing mismeasurement and allowing the possibility of explaining TFP growth (Jorgenson and Griliches 1967). A fourth limitation is that the study focuses on global patterns, not taking sufficiently into account country heterogeneity. The relative contribution of the determinant indexes to the variance of TFP growth and the impact of the overall determinant index on TFP growth could be different for each country and region, generally depending on the level of economic development and the nature of their political and social environment. Despite these limitations, we expect that this chapter and accompanying toolkit can be a starting point—an international benchmark—for researchers and policy makers in their analysis of productivity and growth for particular countries.[8]

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[8] See, for instance, Céspedes, Loayza, and Ramírez, forthcoming.

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Appendix A. Literature Review

1. Innovation (12 studies)

Study	Country and year	Results	Relationship
Nadiri (1993)	4 industrial countries, 1970–90	The results suggest a positive and strong relationship between research and development (R&D) expenditures and growth of output or total factor productivity (TFP).	+
Coe and Helpman (1995)	22 industrial countries, 1971–90	International R&D spillovers have beneficial effects on domestic productivity. The elasticity of TFP with respect to foreign R&D expenditure is 0.02–0.08 for G7 countries and 0.04–0.26 for other small OECD countries.	+
Chen and Dahlman (2004)	92 countries, 1960–2000	The number of patents and journal publications is statistically significant in terms of real GDP growth via their effects on the TFP growth rate.	+
Furman and Hayes (2004)	29 countries, 1978–99	Innovation-enhancing policies and infrastructure need to be developed to achieve leadership in innovation, but these are insufficient unless coupled with ever-increasing financial and human capital investments in innovation.	+/–
Griffith, Redding, and Reenen (2004)	12 OECD countries, 1974–90	R&D is statistically and economically important in both technological catch up and innovation. Human capital also plays a major role in productivity growth.	+
Guellec and van Pottelsberghe de la Potterie (2004)	16 OECD countries, 1980–98	R&D performed by the business sector, the public sector, and foreign firms is a significant determinant of long-term productivity growth.	+
Ulku and Subramanian (2004)	30 OECD countries, 1981–97	The results suggest a positive relationship between per capita GDP and innovation in both OECD and non-OECD countries. However, the effect of the R&D stock on innovation is significant only in the OECD countries with large markets.	+/–
Jorgenson, Ho, and Stiroh (2005)	United States, 1990s and 2000s	Industries that produce or use information technology (IT) account for only 30% of U.S. GDP but contributed to one-half of the acceleration in economic growth in the 1990s and 2000s.	+
Abdih and Joutz (2006)	United States, 1948–97	Long-run elasticity of TFP with respect to the stock of patents is positive, but small. These results seem to suggest that while research workers benefit greatly from "standing on the shoulders" of prior researchers, the knowledge that they produce seems to have complex and slowly diffusing impacts on TFP.	+
Jorgenson, Ho, and Stiroh (2008)	United States 1960–2006	Information technology was critical to the dramatic acceleration of U.S. labor productivity growth in the mid-1990s.	+
Oliner, Sichel, and Stiroh (2008)	United States, 1990s–2000s.	Authors confirm the central role for IT in the productivity revival during 1995–2000 and show that IT played a significant, though smaller, role after 2000.	+

Study	Country and year	Results	Relationship
Ark, O'Mahony, and Timmer (2008)	United States, Europe, 1980s–2000s	The slow-down in productivity in Europe can be attributed to the slower emergence of the knowledge economy in Europe compared to the United States. Explanations include lower growth contributions from investment in information and communication technology in Europe, the relatively small share of technology-producing industries in Europe, and slower multifactor productivity growth (a proxy for advances in technology and innovation).	+

2. Education (9 studies)

Study	Country and year	Results	Relationship
Benhabib and Spiegel (1994)	78 countries, 1965–85	Human capital is not significant in explaining per capita growth rates. However, the growth rate of TFP depends on a nation's human capital stock level.	+
Miller and Upadhyay (2000)	83 countries, 1960–89	Human capital generally contributes positively to TFP. In poor countries, human capital interacts with openness to achieve a positive effect, on balance.	+/–
Barro (2001)	100 countries, 1965–95	Growth is significantly related to the years of schooling at the secondary and higher levels for males and students' test scores (a proxy for the quality of education). The insignificant relationship between growth and years of schooling for females implies that women are not well utilized in the labor markets of many countries.	+/–
Griffith, Redding, and Reenen (2004)	12 OECD countries, 1974–90	Human capital (percentage of higher school attained in the total population) affects the rate of convergence of TFP growth.	+
Benhabib and Spiegel (2005)	27 countries, 1960–95	Results support that human capital plays a positive role in the determination of total factor productivity growth rates through its influence on the rate of technology catch-up.	+
Bronzini and Piselli (2009)	Italy, 1985–2001	Elasticity of TFP with respect to years of schooling is positive and statistically significant (0.379).	+
Coe, Helpman, and Hoffmaister (2009)	24 countries, 1971–2004	Authors find evidence that countries where the ease of doing business and the quality of tertiary education systems are relatively high tend to benefit more from their own R&D efforts, from international R&D spillovers, and from human capital formation.	+
Erosa, Koreshkova, and Restuccia (2010)	United States, 1990–95	Human capital accumulation strongly amplifies TFP differences across countries.	+

Study	Country and year	Results	Relationship
Wei and Hao (2011)	China, 1985–2004	School enrollment has significant and positive effects on the TFP growth of Chinese provinces. When education quality (as measured by the teacher-student ratio and government expenditure on education) is incorporated, TFP growth appears to be significantly enhanced by quality improvements in primary education at the national level. TFP growth is significantly associated with secondary education in the eastern region; with primary and university education in the central region; and with primary education in the western region.	+

3. Market Efficiency (21 studies)

Study	Country and year	Results	Relationship
Coe, Helpman, and Hoffmaister (1997)	77 developing countries, 1971–90	Based on data for 77 developing countries, R&D spillovers via trade with 22 industrial countries are substantial.	+
Borensztein, De Gregorio, and Lee (1998)	70+ countries, 1970–89	Foreign direct investment (FDI) contributes to economic growth only when a host economy has sufficient capability to absorb advanced technology.	+/–
de Mello (1999)	16 OECD and 17 non-OECD, 1970–90	FDI has a positive relationship with TFP growth in OECD countries, but a negative relationship in non-OECD countries.	+/–
Fagerberg (2000)	39 countries, 1973–90	While structural change on average has not been conducive to productivity growth, countries that have managed to increase their presence in the technologically most progressive industry (electronics) have experienced higher productivity growth than other countries.	+/–
Foster, Haltiwanger, and Krizan (2001)	United States, 1977–87	The contribution of reallocation of outputs and inputs from less productive to more productive establishments plays a significant role in accounting for aggregate productivity growth.	+
Nicoletti and Scarpetta (2003)	18 OECD countries, 1984–98	Productivity growth is boosted by reforms that promote private corporate governance and competition. In manufacturing, the productivity gains from liberalization are greater the further a given country is from the technology leader. Strict product market regulations—and lack of regulatory reforms —appear to underlie the meager productivity performance in industries where Europe has accumulated a technology gap.	+

Study	Country and year	Results	Relationship
Peneder (2003)	28 OECD countries, 1990–98	Structural change generates positive as well as negative contributions to aggregate productivity growth. Because many of these effects net out, structural change on average appears to have only a weak impact. Given that certain industries systematically achieve higher rates of productivity growth and expansion of output than others, structural change in favor of specific industries might still be conducive to aggregate growth.	+/–
Alfaro, Chanda, Kalemli-Ozcan, and Sayek (2004)	49+ countries, 1975-95	FDI alone plays an ambiguous role in contributing to economic growth. However, countries with well-developed financial markets gain significantly from FDI.	+
Dollar and Kraay (2004)	~100 developing and developed countries, 1960s–90s	Large increases in trade and significant declines in tariffs lead to faster growth and poverty reduction in poor countries.	+
Jerzmanowski (2007)	79 developing and developed countries, 1960–95	Inefficiency appears to be the main explanation for low incomes throughout the world; it explains 43% of output variation in 1995, and its importance has increased over time. Countries with an inadequate mix of inputs are unable to access the most productive technology. The world technology frontier appears to be shifting out faster at input combinations close to that of the R&D leader.	+
Mendi (2007)	16 OECD countries, 1971–95	Within OECD countries that are not in the G7, technology imports increase the host country's TFP. The effect is stronger in the initial years of the sampling period. There is no evidence on this positive effect of technology trade on productivity among G7 countries.	+/–
Arnold, Nicoletti, and Scarpetta (2008)	OECD countries, 1985–2004	Tight regulation of services has slowed down growth in sectors that use IT by hindering the allocation of resources toward the most dynamic and efficient firms. Regulations especially hurt firms that are catching up to the technology frontier and that are close to international best practice.	+
Chanda and Dalgaard (2008)	40+ countries, 1985	A development accounting analysis suggests that as much as 85% of the international variation in aggregate TFP can be attributed to variation in relative efficiency across sectors.	+
Haltiwanger, Scarpetta, and Schweiger (2008)	16 industrial and emerging economies, 1990s	Hiring and firing costs tend to curb job flows, particularly in those industries and firm size classes that require more frequent labor adjustment.	+
Lentz and Mortensen (2008)	Denmark, 4900 firms, 1992–97	The estimated model implies that more productive firms in each cohort grow faster and consequently crowd out less productive firms in steady state. This selection effect accounts for 53% of aggregate growth in the estimated version of the model.	+
Alfaro, Kalemli-Ozcan, and Sayek (2009)	60+ countries, 1975–95	Countries with well-developed financial markets gain significantly from FDI via TFP improvements.	+/–

Study	Country and year	Results	Relationship
Bridgman, Qi, and Schmitz (2009)	United States, sugar manufacturing firms, 1934–74	Government's enforcement on domestic and import sales quotas significantly distorted sugar production at each factory and the location of the industry.	+
Chang, Kaltani, and Loayza (2009)	82 countries, 1960–2000	The growth effects of openness may be significantly improved if certain complementary reforms are undertaken in the areas of investment in education, financial depth, inflation stabilization, public infrastructure, governance, labor market flexibility, ease of firm entry, and ease of firm exit.	+
Hsieh and Klenow (2009)	China (1998–2005) and India (1987–95) vs. United States (1977–97)	When capital and labor are hypothetically reallocated to equalize marginal products to the extent observed in the United States, manufacturing TFP gains are expected to be substantial in China and India.	+
Petrin and Sivadasan (2011)	Chile, manufacturing firms, 1982–94	Comparing blue- and white-color labor in terms of the marginal product and cost of an input suggests that the increase in severance pay is associated with the decrease in allocative efficiency.	+
Bartelsman, Gautier, and De Wind (2016)	European countries, United States, 1980s–2000s	Countries which have extensive employment protection legislation (EPL) benefit less from the arrival of new risky technology than countries with limited EPL. The model is consistent with the slowdown in productivity in the European Union relative to the United States since the mid-1990s.	+

4. Infrastructure (11 studies)

Authors	Country and year	Results	Relationship
Aschauer (1989)	United States, 1949–85	There is a large return to public investment.	+
Munnell (1992)	Not applicable	On balance, public investment has a positive effect on private investment, output, and employment growth.	+
Hulten (1996)	4 East Asian and 17 African countries, 1970–90	25% of the growth difference between East Asia and Africa is due to inefficient use of infrastructure. This result may partly proxy for TFP differences.	+
Pritchett (1996)	~100 countries, thought experiment	Pritchett presents theory and calculations to show that part of the explanation of slow growth in many poor countries is not that governments did not spend on investments, but that these investments did not create productive capital. A variety of calculations suggest that in a typical developing country, less than 50 cents of capital were created for each public dollar invested.	+/–
Galiani, Gertler, and Schargrodsky (2005)	Argentina, 1990s	Improved water services are associated with significant reductions in deaths from infectious and parasitic diseases.	+
Canning and Pedroni (2008)	>40 countries, 1950–92	While infrastructure does tend to cause long-run economic growth, there is substantial variation across countries.	+

Authors	Country and year	Results	Relationship
Straub (2008)	140 countries, 1989–2007	Good infrastructure allows firms to have more productive investments in machinery, reduces time wasted commuting, promotes better health and education, and so on. The analysis obtains positive effects of infrastructure on growth when it uses physical indicators of infrastructure. However, the effects are not clear when infrastructure investment flows are used as proxies for infrastructure.	+/–
Calderón and Servén (2010)	>100 countries, 1960–2005	The estimates illustrate the potential contribution of infrastructure development to growth and equity across Africa.	+
Loayza and Odawara (2010)	Egypt, Arab Rep., 1971–2005	An increase in infrastructure expenditures from 5 to 6 percent of gross domestic product would raise the annual per capita growth rate of GDP by about 0.5 percentage points in a decade's time and 1.0 percentage point by the third decade.	+
Calderón and Servén (2012)	Latin America, 1981–2005	Poor infrastructure is a key obstacle to economic development. The experience of Latin America shows that there is no question that private participation did deliver some efficiency and quality gains. But they were held back by weak regulatory and supervisory frameworks, and poorly designed concession and privatization agreements, which led to ubiquitous renegotiations and ended up costing governments enormous sums.	+
(Calderón and Servén 2014)	Not applicable	Recent theoretical and empirical literature finds positive effects of infrastructure development on income growth and, more tentatively, on distributive equity.	+

5. Institutions (10 studies)

Study	Country and year	Results	Relationship
Barro (1991)	98 countries, 1960–85	Growth is inversely related to the share of government consumption in GDP, but insignificantly related to the share of public investment. Growth rates are positively related to measures of political stability and inversely related to a proxy for market distortions.	+/–
Przeworski and Limongi (1993)	Review of previous studies	Political institutions do matter for growth, but thinking in terms of regimes, democracy, autocracy, or bureaucracy does not seem to capture the relevant differences.	+/–
Sachs (2003)	60+ countries, 1995	The transmission of malaria, which is strongly affected by ecological conditions, directly affects the level of per capita income after controlling for the quality of institutions.	+/–

Study	Country and year	Results	Relationship
Hall and Jones (1999)	100+ countries, 1986–95	Output is driven by differences in institutions and government policies, which the authors call "social infrastructure." The authors treat social infrastructure as endogenous, determined historically by location and other factors captured in part by language.	+
Ghali (1999)	10 OECD countries, 1970–94	A big government size causes economic growth with some disparities, through the increase of government spending, investment, or international trade.	+/–
Dar and AmirKhalkhali (2002)	19 OECD, 1971–99	Total factor productivity on average is weaker in countries where government size is larger due to policy-induced distortions, such as burdensome taxation, crowding-out effects for new capital that embodies new technology, and the lack of market forces that could foster efficient use of resources.	+/–
Easterly and Levine (2003)	64+ countries, 1995	Tropics, germs, and crops affect development through institutions. No evidence is found that tropics, germs, and crops affect country incomes directly other than through institutions. Macroeconomic policies on development are not significant once the factor of institutional quality is controlled.	+
Acemoglu, Johnson, and Robinson (2004)	Korea, Rep., colonized countries by European powers	Differences in economic institutions, rather than geography or culture, cause differences in per capita incomes. Countries with more secure property rights (that is, with better economic institutions), have higher average incomes.	+
Rodrik, Subramanian, and Trebbi (2004)	79+ countries, 1995	The study estimates the respective contributions of institutions, geography, and trade in determining income levels around the world, using recently developed instrumental variables for institutions and trade. Results indicate that the quality of institutions "trumps" everything else.	+
Chanda and Dalgaard (2008)	40+ countries, 1985	The study compiles a Government Anti-Diversionary Policy index (GADP), an average of five indices capturing the quality of government: rule of law, bureaucratic quality, risk of expropriation, government repudiation of contracts, and corruption. The GADP is strongly related to total factor productivity. Introducing geographical variables reduces the impact of GADP considerably. Geographical explanations seem to be as important as institutional explanations.	+

Chapter 4

Assessing the Effects of Natural Resources on Long Term Growth: An Extension of the World Bank Long Term Growth Model[1]

Norman V.Loayza, Arthur Mendes, Fabian Mendez Ramos, and Steven Pennings[2]

Abstract

This chapter extends the World Bank's Long Term Growth Model (LTGM) with the addition of a natural resource sector to analyze how long-run growth evolves in resource-rich countries and the growth impacts of price shocks and resource discoveries. In the LTGM-Natural Resource Extension (LTGM-NR), commodity price shocks affect long-term economic growth through physical investment rates. As a large share of resource income typically accrues to the government, the size of the boost to investment in a price boom depends on the government's fiscal rule. Fiscal rules that prioritize public investment, like a Hartwick Rule, generally lead to the largest increases in long-term growth. However, structural surplus rules, which save commodity revenues, can also boost growth if they free up savings for private investment. The response of incomes to discoveries of natural resources is similar to the response to price shocks, although discoveries also produce a direct effect on real GDP, in addition to an indirect effect through investment. The LTGM-NR also captures the effect of other (non-resource) growth fundamentals in resource-rich economies, and it is better suited to general growth analysis in these countries than the standard LTGM. However, the LTGM-NR is a supply-side model, and so does not capture the short-run effects of price and discovery shocks that operate through aggregate demand.

JEL: O13, O41, 023, Q33, Q43.
Keywords: Long-term growth, neoclassical model, natural resources, fiscal rules.

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[1] **Editors' note:** This chapter is a reprint of World Bank Policy Research Working Paper WPS 9965, originally published in March 2022. The appendixes and spreadsheet-based LTGM-NR tool are available at the Long Term Growth Model website: https://www.worldbank.org/LTGM. Affiliations are based on when the paper was written, not necessarily current affiliations.

[2] Norman V.Loayza, Arthur Mendes, Fabian Mendez Ramos, and Steven Pennings, World Bank. Corresponding author email: spennings@worldbank.org. The views expressed here are the authors' and do not necessarily reflect those of the World Bank, its executive directors, or the countries they represent. The authors appreciate helpful comments from Sharmila Devadas, Lay Lian Chuah, Jorge Luis Guzman, Young Eun Kim, and seminar participants at the World Bank's Development Research Group hub in Kuala Lumpur, Bank of Mexico, and Economic Commission for Latin America and the Caribbean.

1. Introduction

The celebrated Solow-Swan neoclassical growth model analyzes how long-run economic growth depends on growth fundamentals, such as productivity, savings/investment, human and physical capital, and demographic trends (Solow 1956; Swan 1956; Mankiw, Romer, and Weil 1992; Hall and Jones 1999). The World Bank's Long Term Growth Model (LTGM; chapter 1 of this volume) is in this tradition, though it is applied to simulations of future growth in developing countries. However, standard neoclassical models are inappropriate for economies where the natural resource sector is sufficiently large to have a first-order effect on growth, including many developing countries. Traditional neoclassical models are also silent on how commodity price shocks and resource discoveries affect long-term growth for commodity exporters, and the economic consequences of government policies that manage resource wealth.

The Long Term Growth Model–Natural Resource Extension (LTGM-NR) seeks to fill this gap by augmenting an otherwise-standard neoclassical growth model with a natural resource sector and government fiscal policy. The model is designed to be accessible and transparent—a spreadsheet-based toolkit (without macros) is freely downloadable at https://www.worldbank.org/LTGM with preloaded data for 56 resource-rich countries (see appendix, table 1 for a list of available countries). The LTGM-NR first allows for the evaluation of how commodity price shocks and discoveries of natural resources affect a country's medium to long-term economic growth and how it depends on different fiscal frameworks. Second, the model analyzes how standard growth fundamentals, such as human capital, demographics, and productivity, affect growth in resource-rich economies. The LTGM-NR allows for a more accurate analysis of the effect of these fundaments than one-sector models, as those models do not account for heterogeneity across sectors or the consequences of depleting reserves of natural resources. However, as the LTGM-NR is a supply-side model, it does not capture the short-run effects of price and discovery shocks that operate through aggregate demand.

The first step in analyzing country-specific commodity price shocks or discoveries is a resource accounting exercise that evaluates the size of resource exports and reserves in each country, and hence the scale of the direct impact of a given change in commodity prices or a resource discovery. We make this easier by providing preloaded data on the resource sector in 56 countries. Our simulations incorporate some often misunderstood accounting identities, such as the fact that commodity price fluctuations only directly affect gross domestic income (GDI), whereas real gross domestic product (GDP) changes only indirectly (as real GDP fixes the price of exports; see Kehoe and Ruhl 2008).

The second step is to trace out how higher GDI and government resource revenues affect investment rates and long-term growth. As in a standard neoclassical model, a higher income boosts private savings (assumed to be a fixed share of GDI) and, consequentially, private investment. But more important—since a large share of the resource income typically accrues to the government—is how the government's fiscal policy affects investment.[3] In short, fiscal rules that generate the largest increases in investment will generate the fastest growth in the medium and long terms.

The LTGM-NR has two submodels: the *LTGM-NR-Default*, in which public investment responds directly to fiscal policy via a simple fiscal rule, and the *LTGM-NR-External-Balance* that considers more sophisticated fiscal rules and the relationship between public savings and the international capital flows.

[3] Cross-country evidence suggests that governments retain on average 65–85 percent of rents in the hydrocarbons sector and 40–60 percent of rents in the mining sector (IMF 2012).

Table 4.1: Taxonomy of Fiscal Rules for Government Resource Revenues

		Spending allocation	
		Mostly Govt. consumption (Historical budget shares)	**Public investment** (Hartwick rule)
Timing of spending	**Spent on impact** (Balanced budget rule)	BBR	BBR-HR ("HR" in Default submodel)
	Save for the future (Structural surplus rule)	SSR	SSR-HR (Not in Default submodel)

Note: BBR = Balanced Budget Rule; SSR = Structural Surplus Rule; HR = Hartwick Rule.

The fiscal rules in both submodels are classified by whether the government saves or spends any extra resource revenues, and if it spends them, whether that spending falls on public investment or government consumption. For a temporary commodity price shock, a *Balanced Budget Rule (BBR)* is when the government spends the extra revenues and a *Structural Surplus Rule (SSR)* when they are mostly saved in financial assets. We usually assume that the spending allocation across investment/government consumption is kept constant, but if all the extra spending is on public investment, we call it a *Hartwick Rule (HR)*. This yields four rules with different combinations of spending/savings and spending allocations: BBR, BBR-HR, SSR, and SSR-HR (see Table 4.1).[4]

The LTGM-NR-External-Balance also analyzes how resource revenues and different fiscal rules interact with international capital flows. This mostly affects the SSR, which often leads to large movements in international borrowing/lending. Most important is the effect on the current account balance and private investment. If the current account and private savings are relatively fixed, the extra public savings through an SSR can crowd in private investment dollar-for-dollar, leading the SSR to have a similar path for investment and growth as a BBR-Hartwick rule. In contrast, without crowding-in of investment (full adjustment of the current account), the SSR in the External-Balance model performs similarly to that of the simple model (which abstracts from international flows). Of course, real-world countries are somewhere in between these two extremes, and so the strength of crowding in is chosen via a parameter that is calibrated to match the data. In addition, the reduced international borrowing generated by a fiscal surplus under an SSR can reduce the government's interest bill—through reduced borrow and lower interest rates—which can free up funds for public investment in the long run under the SSRs.

Angola case study. To illustrate how the LTGM-NR works, we discuss three simulations with the model calibrated to Angola. First, we simulate the baseline "business-as-usual" growth path for Angola over the next three decades. We find that, in the absence of major economic shocks or reforms, potential GDP per capita growth declines slightly in the medium term but is expected to pick up in the longer term. A growth decomposition shows that the "U-shaped" dynamics are driven by the interaction of improving demographic trends, depleting oil reserves, and a transition of the economy away from oil. Finally, we show that an unadjusted ("naïve") calibration of the standard LTGM would generate an overly optimistic growth path for Angola. This is because a one-sector model cannot account for the depletion of oil reserves that is a drag on growth and the fact that the oil sector is much more capital intensive than the non-oil sector.

[4] The difference between the SSR and SSR-HR depends on the timing of the analysis. In the short term, revenues are mostly saved, and, consequentially, both rules yield a similar allocation of spending. However, they diverge substantially in the medium and long terms, as fiscal surpluses under the SSRs can improve the government net asset position, freeing up funds for extra spending. In this case, the SSR-HR would lead to a higher path of public investment than the SSR.

Second, we evaluate the effects of a hypothetical oil price boom-and-bust cycle in Angola under each fiscal rule. At the end of the oil price simulation (when oil prices are back at their original level), GDP per capita is highest under the BBR-HR at 20%–25% above the baseline, as all of the higher government oil revenues are invested during the boom years. However, under the other fiscal rules, GDP is only 5%–12% above the baseline because of a much smaller increase in investment. The SSR-HR is the only rule that supports faster growth for several years after the end of the oil price cycle. This is because the interest from the extra savings during the oil price cycle is recycled into the budget, releasing resources for an almost permanent increase in public investment. Third, we find that discoveries have a large and persistent impact on Angola's growth rate, especially under HRs. As before, the LTGM-NR only simulates the supply-side effects of these price shocks and discoveries, not their short effects through aggregate demand.

Related literature. While there is a rich literature on managing the short-term cyclical effects of commodity booms (for example, Kumhof and Laxton 2013; Mendes and Pennings 2020; Pieschacón 2012) and whether natural resources are a curse or a blessing for development (see Van der Ploeg 2011 for a survey), the mechanics of medium- to long-term growth in individual resource-rich economies are much less frequently studied.[5] The closest work is the modeling sections of Hansen and Gross (2018) and Arezki, Ramey, and Sheng. (2018), who evaluate the effect of exploration and discoveries on medium-term macroeconomic aggregates. While these models share some similarities with ours (in particular, the setup of the resource sector), their purposes are very different. Those papers seek to explain estimated empirical relationships, whereas we propose a simple and accessible tool for country-specific growth simulations and policy analysis. Our model is simpler but is calibrated to 56 countries individually, rather than to one representative small open economy.[6]

The remainder of the chapter is organized as follows. Section 2 describes the theoretical underpinnings of the LTGM-NR, and Section 3 discusses a general calibration. Section 4 presents the applications to Angola, and section 5 concludes.

2. Model Description

The point of departure of the LTGM-NR from a standard neoclassical model (like the standard LTGM) is the disaggregation of the economy into non-resource sector (Sector 0) and resource sector (sector R).

The non-resource sector. The structure of the non-resource sector is identical to the standard LTGM. A representative firm employs physical capital and effective labor with a constant returns to scale Cobb-Douglas production function to generate non-resource output, Y_t^0,

$$Y_t^0 = A_t^0 \left(h_t L_t\right)^{\beta} \left(K_{t-1}^0\right)^{1-\beta}, \quad 0 < \beta < 1 \tag{1}$$

where A_t^0 is the total factor productivity (TFP) in sector 0, K_{t-1}^0 is the physical capital in sector 0 at the end of period $t-1$, and β is the labor share in the non-resource sector. Effective labor, $h_t L_t$, is decomposed into h_t human capital per worker, and L_t, the labor force (number of workers). The labor force is defined as $L_t = \varrho_t \omega_t N_t$. Where N_t is total population, ω_t is the working-age to population ratio, and ϱ_t is the labor force

[5] For empirical evidence on the resource curse in developing countries, see Terry Lynn (1999) and Wood (1999). For individual country experience with the resource curse (Ghana and Angola), see Cust and Mihalyi (2017) for Ghana, and Richmond, Yackovlev, and Yang (2013) for Angola. For countries that avoided the resource curve (Chile and Botswana), see Medina and Soto (2007) and AfDB (2016).

[6] Importantly, our model lacks forward-looking decision-making by agents, as this is difficult to incorporate in a spreadsheet-based model.

participation rate (labor force to working-age population ratio). The variables A_t^0, h_t, N_t, ω_t, and ϱ_t are exogenous and evolve at the following annual growth rates: $\bar{g}_t^{A_0}$, $\bar{g}_t^h$, $\bar{g}_t^N$, $\bar{g}_t^\omega$, $\bar{g}_t^\varrho$, respectively. Throughout the model, exogenous variables are indicated with a bar index notation (as in $\bar{g}$).

The natural resource sector. The setup of the natural resource sector builds on Hansen and Gross (2018) and Arezki, Ramey, and Sheng (2017) in being a Cobb-Douglas function of proven reserves (R) and physical capital (K), with decreasing returns in both R and K (equation (2)).[7] This production function has the desired property that the first reserves are relatively easy to extract—for example, being close to the surface—but later reserves require more and more capital (or technology) to generate the same output, as firms are forced to drill further underground or in less accessible locations.[8]

As countries produce multiple commodities, the natural resource sector, *R*, is further disaggregated into *N* non-renewable resource industries $i \in \{1,\ldots,N\}$ (e.g., oil, natural gas, copper, gold, and others). As shown in equation (2), the output of resource industry *i*, Q_t^i, is produced using reserves R_{t-1}^i and physical capital K_{t-1}^i in that industry,

$$Q_t^i = A_t^i \left(K_{t-1}^i\right)^{1-\gamma_i} \left(R_{t-1}^i\right)^{\gamma_i}, \quad 0<\gamma_i<1 \text{ and } i \in \{1,\ldots,N\} \tag{2}$$

where A_t^i is the TFP in industry *i*—which grows at exogenous rate $\bar{g}_t^{A_i}$—and γ_i is the share of resource rents in industry *i* (then, $1 - \gamma_i$ is the capital income share). Capital and reserves are state variables determined in the previous year $t - 1$.

The dynamics of reserves in each industry obey the following law of motion,

$$R_t^i = R_{t-1}^i - Q_t^i + \bar{D}_t^i, \quad i \in \{1,\ldots,\text{N}\} \tag{3}$$

where reserves in industry *i* at the end of period *t*, R_t^i, increases with an exogenous stream of discoveries, $\bar{D}_t^i$, and is endogenously depleted by the production of good *i*, Q_t^i.

Equations (4) and (5) describe the evolution of physical capital in activity $j \in \{0,1,\ldots,N\}$ (non-resource sector plus resource industries) and at the aggregate level, respectively,

$$K_t^j = (1-\delta) K_{t-1}^j + I_t^j, \quad j \in \{0,\ 1,\ldots,N\} \tag{4}$$

$$K_t = \sum_{j=0}^{N} K_t^j \tag{5}$$

where δ is the annual depreciation rate (common across all activities), I_t^j is the investment in activity *j*, and K_t is the aggregate capital at the end of period *t*.

National income/output and prices. The model economy represents a small, price taking, commodity exporter. The non-resource good is freely traded with a constant price of US$1 (the numeraire), and is used for private and government consumption, investment, and imports. All the proceeds from the resource sector are exported at exogenous international prices $\bar{p}_t^i$ in constant dollars.

[7] Hansen and Gross (2018) and Arezki, Ramey, and Sheng (2017) also include labor in the production function, but its share is very small (0.13); so for simplicity we exclude it.

[8] Alternatively, R_t^i can be interpreted as a quality-adjusted index of reserves that take into consideration geological factors such as ore grade (for minerals) or the composition of hydrocarbons (for petroleum and natural gas). As the highest quality mines and oil fields tend to be explored first, further extraction and depletion reduces the quality of the remaining reserves, scaling down the industry marginal product of capital (see Cochilco 2017). However, our default calibration of the model is not adjusted for the quality of reserves.

Real GDP and real GDI. There are two measures of the "size" of an open economy, real gross domestic product (RGDP) and real gross domestic income (RGDI) (also known in the US as "Command-basis GDP").[9] While these two are identical in a closed economy, they are often very different in countries with volatile terms of trade like commodity exporters. The key difference between the measures is how exports are deflated (Kehoe and Ruhl 2008).[10]

For RGDP, exports are deflated by the export price index, which for a country exporting one commodity is simply p_t^1/p_0^1 (the current commodity price relative to its price in the base year, $t = 0$). *This means that changes in commodity prices have no direct effect on $RGDP_t$* (equation (6)). This is unsurprising, as RGDP is designed to be a measure of *quantities*, which are not directly affected by commodity price shocks.

$$RGDP_t = Y_t^0 + \sum_{i=1}^{N} \overline{p}_t^i Q_t^i \,/\, (\overline{p}_t^i / \overline{p}_0^i) = Y_t^0 + \sum_{i=1}^{N} \overline{p}_0^i Q_t^i \tag{6}$$

In contrast, RGDI is a measure of purchasing power: how much can be bought with the national income. Hence, for GDI, exports are deflated by the consumption (or, equivalently, import) price index. In our model, consumption goods are of the non-resource (numeraire) good, and so have a constant price of US$1.[11] Hence RGDI, denoted by Y_t (without a superscript), is just the value of non-resource and resource production (in terms of the numeraire)—as in equation (7),

$$Y_t = Y_t^0 + Y_t^R = Y_t^0 + \sum\nolimits_{i=1}^{N} \overline{p}_t^i Q_t^i \tag{7}$$

While neither RGDP nor RGDI is the "right" measure, we focus more on RGDI. Also, it makes more sense to measure investment and savings relative to RGDI because consumption/investment goods are the numeraire. In this case, let us denote lower case letters variables *as a share of real GDI* (e.g., $z_t \equiv Z_t/Y_t$).

Investment. As in the standard LTGM, capital accumulation is the main endogenous driver of growth in the LTGM-NR. To analyze the effects of different fiscal frameworks on the dynamics of growth in resource-rich countries, we decompose aggregate investment (i_t) into private (i_t^p) and public (i_t^g) investment (see equation (8)), though these are perfect substitutes in the production of new capital.[12] Also, total investment is allocated across sectors and industries of the economy (equation (9)),

$$i_t = i_t^p + i_t^g \tag{8}$$

$$i_t = \sum\nolimits_{j=0}^{N} i_t^j \tag{9}$$

In the LTGM-NR, private investment is an exogenous share of GDI (usually a fixed share), and public investment depends on the government's fiscal rule. The assumption of a fixed share of private investment is a generalization of the Solow-Swan tradition.[13] This generalization is an important departure from the

[9] For the term "real gross domestic income" from the international System of National Accounts (SNA), see https://stats.oecd.org/glossary/detail.asp?ID=2244. The nomenclature can be confusing as the US Bureau of Economic Analysis (BEA) departs from the SNA. The BEA calls GDP(I) (gross domestic product calculated using the income method) GDI; see https://www.bea.gov/resources/learning-center/what-to-know-income-saving, which is why it need to use the term "Command-basis GDI": see https://www.bea.gov/help/glossary/command-basis-gross-domestic-product.

[10] RGDP and RGDI are equivalent in a closed economy.

[11] Commodity exporting economies typically import a wide range of imported goods (often manufactures), and so the assumption of a constant import price is not too unrealistic.

[12] For a variant of the LTGM where public and private investment are differentiated, see Devadas and Pennings (2019).

[13] More specifically, in the closed economy Solow-Swan model (without a government), savings are fixed as a share of GDP, which means that investment is also a fixed share of GDP.

literature (Hansen and Gross 2018; Arezki, Ramey, and Sheng 2017), where agents are forward looking and allocate investment intertemporally based on its costs and benefits. However, the assumption of a fixed share of private investment keeps the LTGM-NR simple and its mechanisms straightforward. The public investment assumption stems from our application to resource-rich economies, where public investment is often funded by commodity revenues. The determinants of investment vary across the LTGM-NR Default and External-Balance submodels, which are discussed further below.

We also need to determine the allocation of aggregate investment across the non-resource and different resource industries. Again, to keep the model simple, this is done via a rule of thumb where investment is allocated across the different activities proportionally to (*i*) the marginal efficiency of capital and (*ii*) the sector's relative size (in terms of capital shares), as below:

$$\frac{i_t^i}{i_t} = \left(\frac{K_{t-1}^i}{K_{t-1}}\right)\left(\frac{MRPK_t^i}{MRPK_t^{DS}}\right)^{\mu}, \quad for \;\; i \in \{1, \ldots, N\} \tag{10}$$

$$MRPK_t^j = (1-\gamma_j)\; \bar{p}_t^j Q_t^j / K_{t-1}^j \;\; for \;\; j \in \{0, 1, \ldots, N\} \tag{11}$$

$$MRPK_t^{DS} = \left[\sum_{j=0}^{N}\left(\frac{K_{t-1}^j}{K_{t-1}}\right)\left(MRPK_t^j\right)^{\mu}\right]^{1/\mu} \tag{12}$$

where $MRPK_t^j$ denotes the marginal revenue product of capital (the dollar value of the marginal product of capital) in activity *j*, $1-\gamma_0 \equiv 1-\beta$, and $MRPK_t^{DS}$ is a Dixit-Stiglitz (DS) aggregator of the MRPK across all activities.[14] The aggregator weights each activity by their capital shares, K_{t-1}^j / K_{t-1}.

While the rule of thumb is not derived from an optimizing framework, it is constructed to allocate investment to more efficient and larger industries (as would be the case in an optimizing framework) and has two other appealing properties. First, across same-size industries, if activity *i* is 1% more efficient than activity *j*, it receives μ% more investment (i.e., if $K_{t-1}^i = K_{t-1}^j \rightarrow \ln(i_t^i / i_t^j) = \mu \ln(MRPK_t^i / MRPK_t^j)$). Second, investment is allocated so that capital shares remain constant across sectors with the same marginal efficiency of capital (i.e., if $MRPK_t^i = MRPK_t^j \rightarrow K_t^i / K_t^j = K_{t-1}^i / K_{t-1}^j$). Moreover, this rule of thumb is simple enough to be solved in a spreadsheet. We usually calibrate $\mu = 1$.

A. The LTGM-NR Default

In this subsection we describe the LTGM-NR-Default submodel which is a simplified version of the LTGM-NR-External-Balance (presented in subsection B) and designed to be more user-friendly. In the LTGM-NR-Default, investment is determined directly—like Model 1 in the standard LTGM—rather than indirectly via international and domestic savings. The simplifications fall into two categories, which are related to the determinants of private and public investment, respectively.

First, private investment is assumed to be an exogenous fraction of GDI, which is our analogue of the standard assumption in a Solow-Swan model. Second, public investment as a share of GDI responds to fluctuations in resource revenues according to the following rule:

$$i_t^g = \bar{i}_t^g + \theta\left(z_t^R - \tilde{z}_t^R\right) + \varepsilon_t \tag{13}$$

[14] Note that equation (10) does not apply for the non-resource sector (0) but equations (11) and (12) do. Investment in the non-resource sector is determined residually as $I_t^0 = I_t - \sum_{i=1}^{N} I_t^i$. However, the normalization of equation (10) by $MRPK_t^{DS}$ ensures that it also holds for the non-resource sector.

where $z_t^R - \breve{z}_t^R$ are cyclical government resource revenues (as a share GDI)—i.e., the deviation of actual resource revenues z_t^R from their "structural" or long-run values $\breve{z}_t^R$ (discussed below). The parameter θ is the marginal propensity to invest resource revenues: the fraction of cyclical resource revenues that is invested each period.[15] The variable $\overline{i}_t^g$ is the exogenous baseline public investment—i.e., public investment as a share of GDI that prevails in the absence of shocks (zero cyclical revenues). The term $\varepsilon_t \equiv -\overline{i}_t^g (z_t^R - \breve{z}_t^R) / \tau_R$ is a technical adjustment to prevent double counting, as increases in commodity production will raise real GDI, and hence i_t^g through the constant term $\overline{i}^g$. ε_t is usually quantitatively small.

Government resource revenues (as a share of GDI), z_t^R, is obtained from a flat tax rate τ_R applied to resource GDI, y_t^R,[16]

$$z_t^R = \tau_R y_t^R \tag{14}$$

The structural revenue, $\breve{z}_t^R$, is based on structural prices, $\breve{p}_t^i$, and output, $\breve{Q}_t^i$:

$$\breve{z}_t^R = \tau_R \sum_{i=1}^{N} \breve{p}_t^i \breve{Q}_t^i \tag{15}$$

The purpose of defining a structural revenue is to smooth out transitory fluctuations in actual revenues. As discussed in section 3, structural prices are usually set at their (perceived) long-term levels. When production is not the focus of the analysis, to keep the model simple, we set structural production equal to actual production or a moving average. However, the LTGM-NR toolkit provides other specifications, such as using baseline as reference production.[17]

Fiscal rules. The marginal propensity to invest, θ, captures the pro-cyclicality of fiscal policy. The user can choose any value of θ, although more common values range between 0 and 1. This range nests three popular fiscal rules:

- $\theta = 0$ captures a SSR (Structural Surplus Rule), as cyclical resource revenues are saved (when prices are high) and do not affect public investment.[18]
- $\theta = \theta^{hist}$ captures a BBR (Balanced Budget Rule), where θ^{hist} is the historical fraction of the expenditure that is spent on public investment. In this case, when the cyclical resource revenue increases by one dollar, all windfall is spent, but only the fraction θ^{hist} in extra spending is channeled to investment (the remaining $1 - \theta^{hist}$ falling on government consumption).
- When $\theta = 1$, all cyclical resource revenue is spent, but it falls only on public investment, as prescribed under a BBR-HR (Balanced Budget—Hartwick Rule).

B. The LTGM-NR External Balance

The LTGM-NR External-Balance submodel keeps the structure of the Default submodel but accounts for the public sector in more detail and allows for a relationship between the public and private investment via the availability of savings.

[15] The LTGM-NR spreadsheet also allows the parameter θ to vary over time.

[16] Capturing, for example, royalties from the concessions of exploration of natural resources, tax-receipts from private extractive enterprises, and profits from state-owned companies.

[17] An equilibrium is defined as a collection of 15 endogenous trajectories $\{Y_t^0, Q_t^i, R_t^i, K_t^j, K_t, RGDP_t, Y_t, i_t, i_t^0, i_t^i, MRPK_t^j, MRPK_t^{DS}\}$ $\{i_t^g, z_t^R, \breve{z}_t^R\}$ where $j \in \{0,1,\ldots,N\}$ with each endogenous variable specified as a function of the exogenous paths $\{\overline{g}_t^{A_j}, \overline{g}_t^h, \overline{g}_t^N, \overline{g}_t^\omega, \overline{g}_t^\varrho, \overline{D}_t^i, \overline{p}_t^i, \overline{\iota}_t^p, \overline{\iota}_t^g, \breve{p}_t^i, \breve{Q}_t^i\}$ and initial conditions $\{GDP_0, GDP_0^j, K_0, K_0^j, R_0^i, p_0^i, N_0, \omega_0, \varrho_0\}$ that satisfy equations (1)–(15) for all t.

[18] In the LTGM-NR-default the SSR and SSR-HR are very similar (given that spending is mostly constant). Hence, we focus on the SSR in the applications of the Default submodel.

The external sector. A key equation in this submodel is the constraint which imposes that aggregate investment must be equal to domestic savings less the current account balance (CAB),

$$i_t = \overline{s}_t^{\,p} + s_t^g - cab_t \qquad (16)$$

where $\overline{s}_t^p$ and s_t^g denote private and public savings, respectively, and cab_t is the current account balance, all expressed as a share of GDI. Public savings are endogenously determined by the fiscal rule in place (details below), and private savings are assumed to be an exogenous share of GDI. The CAB is financed by (exogenous) foreign direct investment (FDI) or newly created external debt (we abstract from other forms of portfolio investment, as they are less common in developing countries):

$$cab_t = -\left[d_t - d_{t-1} / \left(1 + g_t^Y\right)\right] - \overline{fdi}_t \qquad (17)$$

$$d_t = d_t^p + d_t^g \qquad (18)$$

where $\overline{fdi}_t$ denotes FDI in period t, d_t is the outstanding stock of external debt at the end of in period t, both expressed as a share of GDI, and g_t^Y is the net annual growth rate of GDI in period t. Equation (18) decomposes external debt into private and public, d_t^p and d_t^g, respectively.

The relationship between the CAB and fiscal policy is an active debate in the literature and is likely to change substantially from country to country.[19] Much of this literature is about the response of private savings to various shocks (e.g., Loayza, Schmidt-Hebel, and Serven 2000), though in our model we assume private savings are simply a fixed share of GDI. In countries with open capital accounts, an increase in public deficits can be funded by foreign savings—a larger current account deficit, resulting in what is known as the "twin deficits."[20] In contrast, if the current account is relatively fixed as a share of GDI—for example, due to thin capital markets or capital controls—then an increase in public savings could free up financial resources for private investment. Ultimately, we let users choose the degree of crowding in of private investment via a parameter λ:

$$\underbrace{\left(d_t^p - \frac{d_{t-1}^p}{1+g_Y}\right)}_{Private-sector\ deficit} = -\lambda \underbrace{\left(d_t^g - \frac{d_{t-1}^g}{1+g_Y}\right)}_{Fiscal\ deficit} + \overline{d}_t^{\,p} \qquad (19)$$

Where $\overline{d}_t^p$ is the exogenous component of private external debt. Equation (19) implies that a one-dollar fall in public net borrowing crowds in λ dollars of private investment (funded by private net borrowing).[21]

The public sector. The public sector in the External Balance submodel is also more realistic than that in the Default model. The government collects shares τ_R and τ_0 of the resource and non-resource sectors, respectively (equations (20) and (21)). Total revenue is the sum of resource and non-resource revenue (equation (22)). Revenues are used to finance a stream of public expenditure, which is decomposed into government consumption (c_t^g)—which does not affect growth—and public investment (i_t^g) (equation (23)).

[19] Some empirical studies find that higher budget deficits lead to higher current account deficits; others show evidence of the opposite or no significant impact. For a literature review on this subject, see Bussiere, Fratzscher, and Muller (2005) or Cavallo (2005).

[20] Abbas et al. (2011) find that a one percentage point of GDP improvement in the fiscal balance is associated with one-third percentage point improvement in the current account, though it is unclear how much of this adjustment is through private savings.

[21] Note that $i_t^p = \overline{s}_t^{\,p} + \overline{fdi}_t + \left(d_t^p - \frac{d_{t-1}^p}{1+g_Y}\right)$, where $\overline{s}_t^{\,p}$ and $\overline{fdi}_t$ are exogenous. In this case, a fall in the fiscal deficit must be matched by a one-to-one increase in private investment on the left side.

We assume that the split of expenditure between consumption and investment is exogenous and calibrated to match the historical share of public investment in expenditure (see equation (24)):

$$\text{[Non-resource revenue]: } z_t^0 = \tau_0 y_t^0 \quad (20)$$

$$\text{[Resource revenue]: } z_t^R = \tau_R y_t^R \quad (21)$$

$$\text{[Total revenue]: } z_t = z_t^0 + z_t^R \quad (22)$$

$$\text{[Expenditure]: } exp_t = c_t^g + i_t^g \quad (23)$$

$$\text{[Public investment]: } i_t^g = \bar{\eta}_t exp_t \quad (24)$$

where $\bar{\eta}_t$ is the share of expenditure falling on public investment (the remaining $1-\bar{\eta}_t$ on government consumption).

The primary balance is the difference between revenues and non-interest expenditure and represents the government's net borrowing or net lending, excluding interest payments on the outstanding debt (equation (25)). Public savings is defined as revenues less government consumption and represents the amount of resources generated by the government to finance public investment or to pay off the external public debt (equation (26)). Equation (27) describes the evolution of public external debt (as a share of GDI). Each period, the debt grows at the gross rate $(1+r_{t-1})/(1+g_t^Y)$, due to payments on the principal and interest on the outstanding bonds, but decreases one-to-one with the primary balance,

$$\text{[Primary balance]: } b_t = z_t - exp_t \quad (25)$$

$$\text{[Public savings]: } s_t^g = z_t - r_{t-1} d_{t-1}^g - c_t^g \quad (26)$$

$$\text{[Public debt]: } d_t^g = \left(\frac{1+r_{t-1}}{1+g_t^Y} \right) d_{t-1}^g - b_t \quad (27)$$

where r_t is the interest rate and b_t is the primary balance.

Following Schmitt-Grohe and Uribe (2003), the country interest rate is the sum of the world interest rate ($r_w > 0$), assumed to be constant, and a spread proportional to the country's total external debt,

$$r_t = r_W + max\{0, \psi(d_{t-1} - d)\} \quad (28)$$

where ψ is the debt-elasticity of the interest-rate spread, and d is the long-run external debt to GDI ratio.[22] If $d_{t-1} \leq d$, the government can issue debt at the world interest rate, r_W. If $d_{t-1} > d$, an increase in debt of 1 percent of GDI leads to ψ percentage points increase in the country spread.

Fiscal rules. As in the Default submodel, a fiscal rule determines both the timing and composition of government expenditure. The LTGM-NR External Balance allows for four types of rules: BBR, BBR-HR, SSR, and SSR-HR (see Table 4.1), up from three types of rules in the Default submodel (where there is no SSR-HR). The External-Balance submodel defines the timing aspect of fiscal rules in terms of how the primary balance evolves.

[22] For simplicity, the parameter d is usually set to zero or d_0 but the user can choose other values.

The BBR fixes the headline primary balance as a share of GDI at a target $\overline{b}_t$ (usually fixed but could vary over time exogenously) (see top line of equation (29)). This policy leads to pro-cyclical spending: a one-dollar increase (fall) in resource revenues leads to (almost) exactly one-dollar increase (fall) in expenditure.

The SSR mitigates pro-cyclicality by fixing the *structural* primary balance at target $\overline{\breve{b}}_t$. The structural primary balance adjusts for the commodity cycle so that the primary balance tends to increase (decrease) in periods of high (low) commodity prices. More specifically, the structural primary balance is computed based on structural resource revenues, $\breve{b}_t = \breve{z}_t - exp_t$, where the structural revenue, $\breve{z}_t$, is defined as in the Default model (equation (15)). The following equation summarizes the fiscal target under BBRs and SSRs:

$$\text{[Fiscal rule]} \begin{cases} BBR: \; b_t = \overline{b}_t + e_t \\ SSR: \; \breve{b}_t = \overline{\breve{b}}_t + e_t \end{cases} \tag{29}$$

where $e_t = \phi(d^g_{t-1} - d_g)$ adjusts the target by a fraction ϕ of the deviation of the public debt-to-GDI ratio from its long-run level, d_g, thus ensuring debt sustainability. The parameter ϕ ensures the stability of the public debt and controls its volatility.[23]

The BBR and SSR can either keep the composition of spending constant or try to increase investment as in table 4.1. As in the Default submodel, the high-investment rule is called a Hartwick rule (HR), though its application here is more complicated and closer to how it is applied in practice. The principle behind the HR is to prevent extra revenues earned from exhaustible natural resource from being used to finance government consumption. Accordingly, under an HR, all cyclical resource revenue must be invested either in physical or financial assets.[24] The rule is implemented by adding the following inequality to the model:

$$SBI_t \equiv c^g_t \,/\, z^0_t \leq \overline{SBI}_t \quad (\text{usually}, \overline{SBI}_t = 1)$$

this inequality states that the Sustainable Budget Index (SBI), the ratio of government consumption to non-resource revenues, must be equal or lower than an exogenously determined threshold $\overline{SBI}_t$ (typically set to one for all t). An $SBI_t > 1$ means that government consumption is being financed at least partially by resource revenues. An $SBI_t < 1$ means that resource revenues are being invested either in physical or financial assets, while consumption is being financed only from non-resource revenues. Capping the SBI_t to one ensures that assets are being preserved (for a detailed discussion, see Lange and Wright 2004).[25]

The standard SBI rule (with $\overline{SBI}_t = 1$) works well for governments with moderate dependence on resource revenues but might be too restrictive for countries where resource revenues represent a large part of the budget. For example, Angola's fiscal oil revenues account for more than 80 percent of total revenues. In this case, it is inevitable that oil revenues are partially consumed to run basic functions of the government. For that reason, the user of the LTGM-NR can choose any positive value for $\overline{SBI}_t$. A possibility is to set $\overline{SBI}_t$ to c^g_0 / z^0_0 implying that the SBI_t cannot increase over time (as in section 4.B).[26] Although this configuration does not match perfectly the asset-preservation principle, it prevents the government from increasing consumption in times of high resource revenues.

[23] Condition $\phi > (1 + r_W)/(1 + g^Y)$ ensures that the debt-to-GDI ratio fluctuates within bounds around the long-run level. In the limit $\phi \to \infty$ the fiscal rule collapses to a debt-rule: $d^g_t = d_g$.

[24] Some countries consider spending on education and health as investment in human capital, so the HR would not constrain this type of expenditure.

[25] Botswana is the most celebrated country to incorporate the SBI rule in its fiscal framework for diamond revenues (AfDB 2016).

[26] Another possible application is to set $\overline{SBI}_t$ to match historical SBI values.

On the surface, it seems that the HR has no effect when coupled with an SSR, as this rule already saves most of the transitory windfalls in the short run. However, the HR prevents the government from increasing consumption over time as the financial returns on the invested assets start to improve the fiscal budget.[27]

3. General Baseline Calibration

In this section, we describe how to calibrate the LTGM-NR to a generic oil exporter for a "business-as-usual" baseline simulation. The discussion below intends to be comprehensive and provide a detailed description of the calibration. The general reader that is more interested in how the LTGM-NR works in practice can jump ahead to the Angolan exercise in section 4.

The baseline simulation runs from 2021 to 2050 (though the simulation horizon can be changed). "Flow" variables are usually calibrated to a 20-year average (2000–2019) to reduce year-to-year volatility—also, 2019 is before COVID-19—and slow-moving "stock" variables are calibrated to the most recent year available. Many of the parameters are common to the standard LTGM (indicated with a red cross on Table 4.2) and so are not discussed further here (see chapter 1). However, other similar parameters need to be adjusted, as aggregate data sets like the Penn World Tables (PWT) do not include a resource sector. The user has the ability to override the default calibration if they have better data. If the data are missing, we suggest using an average within the same income group or region. Table 4.2 provides an overview of the calibration and data sources.

Parameters. The labor share is set to match the average share of labor compensation in non-resource GDP over 2000–2019. This requires adjusting the PWT labor share, which applies to the whole economy and is usually less labor intensive than the non-resource sector. Specifically:

$$\beta_t = \beta_t^{PWT} \text{ x } GDP_t \ / \ GDP_t^0$$

where β_t^{PWT} is the share of labor compensation in GDP in period t, taken from Penn World Table 10 (PWT10), and GDP_t^0 is non-resource GDP in period t. The baseline calibration sets β equal to the average value of β_t over recent years.

To calibrate the resource rents in resource industry i, γ_i, we use information on natural resource rents shares, provided by the Global Trade Analysis Project (GTAP), and averaged over 2004, 2007, 2011, and 2014.[28]

The tax rate in the resource sector, τ_R, is calibrated using data on government natural resource revenues and resource GDP from the International Monetary Fund's (IMF's) World Commodity Exporters Dataset (IMF-WCE). Specifically, τ_R is set to match the longest available historical average of resource revenues as a share of resource GDP since 2000.

The fiscal rule in the Default submodel requires the calibration of the marginal propensity to invest, θ (see equation (13)). For BBR-HR and SSR, θ is set to one and zero, respectively. For BBR, θ is the average ratio

[27] An equilibrium in the External-Balance submodel is defined as a collection of 12 endogenous trajectories $\{Y_t^0, Q_t^i, R_t^i, K_t^j, K_t, RGDP_t, Y_t, i_t, i_t^0, i_t^i, MRPK_t^j, MRPK_t^{DS}\}$ plus 14 endogenous variables (that are specific to this submodel) $\{i_t^p, s_t^g, cab_t, d_t, d_t^p, d_t^g, z_t^0, z_t^R, z_t, exp_t, c_t^g, i^g, b_t, r_t\}$ where $j \in \{0,1,\ldots,N\}$ with each endogenous variable specified as a function of the exogenous paths $\{\overline{g}_t^{A_j}, \overline{g}_t^h, \overline{g}_t^N, \overline{g}_t^\omega, \overline{g}_t^\varrho, \overline{D}_t^i, \overline{p}_t^i, \breve{p}_t^i, \breve{Q}_t^i\}$ and $\{\overline{s}_t^p, \overline{fdi}_t, \overline{\eta}_t, \overline{b}_t\}$ as well as initial conditions $\{GDP_0, GDP_0^j, K_0, K_0^j, R_0^i, p_0^i, N_0, \omega_0, \varrho_0, d_0^p, d_0^g\}$ that satisfy equations (1)–(12) and equations (16)–(29) for every period t. For HRs, the SBI inequality must also hold for a specified path $\overline{SBI}_t$ at all periods.

[28] We can map parameter γ_i into the measure of natural resource rents from GTAP as it quantifies the total income that can be generated from the extraction of natural resources, less the cost of extraction, including the return on capital employed on the extractive activity.

Table 4.2: Baseline Setup of the LTGM-NR: selected parameters, initial conditions, and trajectories of exogenous variables (Symbol + indicates the parameter is taken from the standard LTGM)

	Model	Source	Time series
A. Parameters			
Depreciation rate (δ) +	Both	PWT 10	2000–2019 average
Labor share, non-res. sector (β_0)	Both	PWT 10	2000–2019 average
Resource rents share (γ_i)	Both	GTAP	2004–2014 average
Resource tax rate (τ_R)	Both	IMF-WCE	2000–2016 average
Non-resource tax rate (τ_0)	EBM*	WEO/WCE	2000–2016 average
World real interest rate (r_W)	EBM	FRED	US long-run real interest rate ≈2%
Debt-elasticity of spread (ψ)	EBM	SGU (2003)	Ranges between 0.001 and 0.100
Private investment crowd-in (λ)	EBM	Chinn et al. (2011)	Average of industrial and EMDEs
Marginal propensity to invest (θ)	Default	IMF-FAD	BBR: 2000–2017 average of investment to expenditure ratio; SSR: θ = 0; HR: θ = 01
B. Initial conditions			
GDP per capita +	Both	WB-WDI	2020 (or most recent)
Exports of oil (% of GDP)**	Both	UN-CT	2002–2019 average
Capital to GDP ratio: +	Both	PWT 10	2019 or most recent
Non-R sector	Both	Endogenous	Equalize initial MRPK
R sector (oil)	Both	Endogenous	Equalize initial MRPK
Reserves of oil	Both	BP/USGS	Most recent
External public debt (% GDP)	EBM	WB-WDI	2020 (or most recent)
External private debt (% GDP)	EBM	WB-WDI	2020 (or most recent)
C. Trajectory of exogenous variables, 2021–2050			
Price of oil (2010 US$/barrel)	Both	WB-CPD	Most recent or 2000–2019 average
Discoveries of oil (barrels/year)	Both	BP/USGS	2000–2019 average
TFP growth, non-R sector	Both	PWT 10	2000–2019 average
TFP growth, oil sector	Both	—	Country-specific
Human capital+	Both	PWT 10	2000–2019 average
Population+(total, working-age)	Both	ILO	Forecast for 2021–2050
Private savings (% GDI)	EBM	WB-CPD	2000–2019 average
FDI+ (% GDI)	EBM	WB-WDI	2000–2019 average
Private investment (% GDI)	Default	IMF-FAD	2000–2019 average
Exogenous public investment †	Both	IMF-FAD	2000–2019 average
Target primary balance (% GDI)	EBM	IMF-WEO	Country-specific
Exogenous private external debt	EBM	—	Country-specific

Note: * EBM denotes External-Balance Model. ** For simplicity, we assume that the resource sector has one industry: oil ($N = 1$). In practice, the user can choose up to three industries from the set of commodities: coal, copper, diamond, gas, gold, iron, lead, nickel, oil, silver, tin, and zinc
† Default model: exogenous public investment (% of GDP); External-Balance Model: exogenous public investment (% of total expenditure).

of public investment to total expenditure over 2000–2019, taken from the IMF-World Economic Outlook (WEO) and the Investment and Capital Stock Dataset provided by the IMF Fiscal Affairs Department (IMF-FAD).

The External-Balance model requires five additional parameters: the private investment crowd-in parameter λ, the average tax rate on the non-resource economy τ_0, the debt-elastic interest spread ψ, the world real interest rate r_W, and how the budget balance responds to debt ϕ. λ measures the response of private investment to the fiscal balance (equation (19)). Its default value is set to 0.15 (a one-dollar increase in net government borrowing crowds in 15 cents of private investment) based on the average of estimates for both industrial and less developed countries (see Chinn, Eichengreen, and Ito 2011). τ_0 is set to match the average ratio of non-resource revenue to non-resource GDP over 2000 (or most recent historical average). Non-resource revenue is calculated as the difference between total revenue and resource revenue, provided by IMF-WEO and IMF-WCE, respectively.[29] Likewise, non-resource GDP is computed as the difference between GDP and resource GDP. The baseline world annual real interest rate, r_W, is set to 2 percent, which is in line with the 10-year inflation-indexed US Treasury bond yields averaged over 2000–2019 from the St Louis Federal Reserve Bank Economic Data (Series: WLTIIT).

The baseline debt elasticity of the interest spread is set to $\psi = 0.1$, which implies that a 10 percent of GDI increase in the external debt leads to a one percentage point increase in the country's interest rate.[30] Finally, we set $\phi = 0.05$, which is sufficient to prevent any explosive paths for public debt as $\phi > r_W$.

Initial conditions. GDP for 2020 is taken from World Bank's World Development Indicators (WB-WDI), in constant 2010 U.S. dollars.[31] In the absence of a data set containing comprehensive information on GDP at the industry level for several commodity exporting countries, we proxy GDP in resource industry *i* by exports of the resource good *i*. More specifically, GDP in industry *i* is set to match the average value of exports as a share of GDP.[32] The export data are taken from the UN-Comtrade Database (UN-CT), which provides information on export value for all 11 commodities and all 56 countries pre-loaded in the LTGM-NR, with a time series that usually starts in 2002.[33]

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[29] As a complementary data set for government revenues (total, resource, and non-resource), we use ICTD/UN-WIDER Government Revenue Dataset (UN-GRD).

[30] The range of estimates for ψ in literature varies widely across countries and papers. For example, while Schmitt-Grohe and Uribe (2003) set $\psi = 0.001$ to match the volatility of the observed current-account-to-GDP ratio for Canada, Schmitt-Grohe and Uribe (2016) estimate $\psi = 1$ for Argentina. We adopt $\psi = 1$ as a compromise between these two seemingly extreme estimates.

[31] LTGM-NR spreadsheet since updated to constant 2015 US dollars.

[32] Initial GDP in industry *i* is computed as a share of total 2020 GDP. The default method is to use average value of exports in industry *i* as a share of GDP since 2000. The following expression describes how the default initial real GDP in industry *i* is computed:

$$GDP^i_{2020} = \underbrace{\left(\frac{1}{N} \sum_{t \geq 2000} \frac{\left(p^i_{2010} / p^i_t\right) \times Exports^{UNCT}_{i,t}}{GDP^{WDI}_t} \right)}_{\text{average share of GDP in industry } i \text{ since 2000}} \times GDP^{WDI}_{2020}$$

where p^i_t is the real price (2010 U.S. dollars) of resource good *i* in period *t* taken from the World Bank Commodity Markets Outlook. $Exports^{UNCT}_{i,t}$ is exports value (current U.S. dollars) of resource good *i* in period *t*, and GDP^{WDI}_t is real GDP in period *t* As $Exports^{UNCT}_{i,t}$ is measured in current U.S. dollars, it is deflated by p^i_t / p^i_{2010}.

[33] Alternatively, we provide a measure of GDP in industry *i* derived directly from production data,

$$GDP^i_{2020} = \underbrace{\left(\frac{1}{N} \sum_{t \geq 2000} \frac{p^i_{2010} Q^{BP/USGS}_{i,t}}{GDP^{WDI}_t} \right)}_{\text{Average share of GDP in industry } i} \times GDP^{WDI}_{2020}$$

where $Q^{BP/USGS}_{i,t}$ is the estimated production of resource good *i* in period *t*. This information is collected from annual reports by a BP-Energy Dataset for energy goods (oil, natural gas, and coal) and from the U.S. Geological Survey for mining goods (cooper, gold, iron, etc.).

As in the standard LTGM, the initial stock of capital-to-GDP ratio is calculated using the most recent observation from PWT 10 (although earlier versions of PWT are also available).[34] The initial capital stock is split across activities to equalize the initial marginal revenue product of capital across $j \in \{0,\ldots N\}$.[35]

Information on the initial stock of reserves in industry i is taken from the BP-Energy Dataset for oil, natural gas, and coal, and from the U.S. Geological Survey Database (USGS) for mining industries, such as copper, gold, and iron. As a stock variable, initial reserves are set to match the most recent observation (usually 2017).

The External-Balance Model also requires initial public and private external debt. Reliable data on the decomposition of external debt into private and public debt are often unavailable for developing commodity exporting countries. Hence, in the baseline calibration, we assume that all initial external debt is public, and initial private external debt is zero. This is obviously an extreme assumption, and country-specific data should be used where available. We calibrate public external debt equal to the most recent observation on total external debt taken from WB-WDI.

Trajectory of exogenous variables. The LTGM-NR requires the trajectories of a number of exogenous variables from 2021 until 2050. The key assumption of baseline simulations is that recent trends will continue in the long term. In this case, we assume that historical averages (such as 2000–2019) will continue until 2050.

The first assumptions are the paths for actual and structural commodity prices. A structural price should reflect its perceived long-term value, so the user could use a long historical average or a proper estimate of the long-run price. For example, in section 4, we set the structural price of oil to US$50/barrel, which is the estimated unconditional mean of oil prices from 1960 to 2020. The actual path of commodity prices can be set to any value. Again, in section 4, we analyze the consequences of an increase in oil prices from US$50 to US$80/barrel. The default data source for commodity prices is the World Bank's Commodities Prices Dataset (WB-CPD–*The Pink Sheet*), although other sources are available (e.g., USGS and BP-Energy). Also, the structural production of resources is usually assumed to follow the N-year moving average of actual production.

Discoveries of natural resources are calibrated using data on annual production and reserves of the resource good i, taken from BP-Energy (for energy industries) and the USGS (for mining). The time series of discoveries of good i in period t is computed as the change in reserves from period $t-1$ to t plus production in period t (as in equation (3)). In the baseline, the trajectory of discoveries of good i from 2020 to 2050 can be set to match the historical average over the past 20 years. Naturally, predicting future discoveries of natural resources is no trivial task, and using historical averages can be misleading. In this case, country-specific data based on experts' knowledge should be used when available.

The LTGM-NR requires paths for future TFP growth in each sector and industry. TFP data at the industry level are usually unavailable for most developing countries. A simple approach is to assume that TFP growth is homogenous across sectors. In this case, we can set TFP growth in each sector/industry equal

[34] In PWT 10 the capital-to-output ratio is computed as rnna/rgdpna, but in some earlier version (e.g. PWT 8.1) is calculated as rkna/rgdpna.

[35] More specifically, the initial capital stock in activity j must satisfy the following $N + 1$ equations,

$$KY^{j}_{2020} = \frac{(1-\gamma_j)GDI^{j}_{2020}}{(1-\beta)GDP^{0}_{2020} + \sum_{i=1}^{N}(1-\gamma_i)GDI^{i}_{2020}} \quad for\ \ j = 0,\ldots,N$$

where $GDI^{j}_{2020} \equiv (\overline{p}^{j}_{t} \,/\, \overline{p}^{j}_{2010})GDP^{i}_{2020}$ denotes real GDI in activity j, year t; and $\gamma_0 = \beta$

to the average aggregate TFP growth over 2000–2019, from PWT 10. When available, the user should use information on sectoral TFP growth.[36]

In the Default submodel, private and public sector investment data are taken from IMF-FAD, which decomposes total investment into private and public from 1960 to 2017. The paths for private investment, $\bar{i}_t^p$, and the exogenous component of public investment, $\bar{i}_t^g$, are set equal their historical averages over 2000-2017, reflecting "business as usual" investment rates.

In the External Balance submodel, private savings, $\bar{s}_t^p$, are set to match the observed average of private savings (% of GDP) in 2000-2019, computed using data from the IMF-WEO and IMF-FAD. Similarly, the share of public investment in total expenditure, $\bar{\eta}_t$, is set to match the average ratio of public investment to total expenditure over 2000–2017 (also IMF-WEO and IMF-FAD). For simplicity, the default fiscal rule is the BBR-Default, with a zero target for the primary balance ($\bar{b}_t = 0$) and stable external public debt ($d^g = d^g_{2020}$), though the user can refer to the IMF-FAD for actual targets for the fiscal balance and debt in specific countries. Finally, the exogenous component of the private debt, $\bar{d}_t^p$ is set to zero by default.

4. Application of the LTGM-NR to Angola

In this section, we illustrate how to apply the LTGM-NR in practice with three exercises for Angola. After a brief discussion of the calibration, we assess the baseline business-as-usual growth path over the next three decades (subsection A), how the long-term growth would be affected by higher oil prices (subsection B) and higher oil discoveries (subsection C). Subsection A compares the LTGM-NR-Default with the standard LTGM (submodel 1). Subsections B and C consider all fiscal rules (BBR, SSR, BBR, SSR-HR) and submodels (Default and External Balance). As before, the LTGM-NR only captures the supply-side of the economy, and not the short-run response of the economy to shocks via aggregate demand.

Calibration to Angola (Default submodel). The calibration to Angola follows the logic of the generic calibration presented in section 3. To keep the description brief, we discuss here only the most important parameters and variables of the Default submodel (for details, see Table 4.3). We calibrate the model with data up to 2020, but the simulation runs from 2023 to 2050. The years 2021–2022 are excluded from the simulation because the LTGM-NR is not suited to account for the short-term volatility induced by the COVID-19 pandemic. Instead, we refer to the IMF's official forecasts for 2021–2022 (see IMF 2021).

We consider oil as the only resource industry in Angola, as oil accounts for virtually the totality of exports (see appendix, table 1). Accordingly, we set the oil sector to account for 40 percent of GDI in 2020 (50.8% of GDP due to different base years), which is consistent with the average size of oil exports in Angola over 2007–2015 (UN-CT data).[37] The labor share in the non-oil sector, β, is set to 0.56 to match the average PWT 10 aggregate labor share of 0.34 (=0.56 x share of non-oil GDI) over 2015–2019. Due to lack of data

[36] For example, the Chilean 2016 Annual Report of the National Productivity Commission documents a large heterogeneity of TFP growth across the copper and non-copper sectors over 2000–2015, with an average fall of 1.0 percent in the copper sector and average growth of 1.4 percent in the non-copper sector.

[37] More specifically, we want to calibrate oil income as a share of GDI consistently with the data collected in terms of GDP. Angola's oil exports at 2010 prices (~$80) averaged 50 percent of GDP over 2007–2015. To transform that information into oil income as a share of GDI, we need to adjust both the numerator (oil exports at 2010 prices) and the denominator (real GDP). First, we scale the numerator by 0.625 (50/80) to express oil income in 2020 oil prices ($50). Second, we compute real GDI in 2020 by scaling real GDP by 0.8 $(\text{i.e.,} 1+(P^{oil}_{2020} / P^{oil}_{2010} - 1)\times share\ of\ oil\ in\ 2020\ GDP \approx 1-0.4\times 0.5)$. That is:

$$\frac{Oil\ Income\ in\ 2020\ prices}{GDI_t} = \frac{Oil\ Income\ in\ 2010\ prices}{GDP_t} \times adjustment = 50\% \times \frac{0.625}{0.8} = 40\%$$

for Angola, we use a cross-country average to calibrate the share of oil rents. More specifically, we set γ^{oil} to 1/3 to match the average share of oil rents across large oil exporters, reported by GTAP (see Appendix Figure 1 for details).

The initial capital-to-GDP ratio is set to 2.0, which is a compromise between PWT 8 (1.7 for 2011) and the World Bank's Macro-Fiscal Model Database (2.2 for 2011).[38] The initial oil reserves are set to 9.5 billion of barrels to match the latest estimates for Angola from BP-Energy.

Although PWT reports TFP data for Angola, identifying trend TFP growth is challenging due to the country's extremely volatile business cycle. Instead, we set non-oil TFP growth to 1 percent to match the average TFP growth in lower-middle-income countries over 2000–2019. The growth rate of oil TFP is set to zero, which is the average TFP growth in large oil exporters over the past two decades (for details, see appendix, figure 2).

Annual human capital growth is set to 0.7 percent, which was the average growth rate in Angola over 2000–2019 (PWT 10). Moreover, we incorporate the UN's forecast of demographic trends for Angola, which suggests that population growth will fall from about 3 percent in 2020 to 2 percent by 2050. The working-age population is predicted to rise from 52 percent of total population in 2020 to 58 percent in 2050. Moreover, based on recent trends, the labor force participation rate is assumed to remain constant at around 80 percent of the working-age population until 2050 (WB-WDI).

We set the government share in the oil sector $\tau_R = 0.7$, which is the historical average of oil revenues (as a share of oil GDP) in Angola over 2001–2013 (IMF-WEC, most recent data available). Private investment is set to 20 percent of GDP to match the average observed in 2000–2017 (IMF-FAD). Due to exceptionally large investments in energy infrastructure, public investment has been historically very high in Angola (above 10 percent of GDP), but is expected to fall significantly over time, especially due to the likely decline in oil revenues. Accordingly, we assume that public investment falls from 6 percent of GDI in 2023 to 2 percent by 2050. The marginal propensity to spend under the BBR is set to $\theta_{BBR} = 0.2$, as public investment averaged 20 percent of total government expenditure from 2000 to 2017 (IMF-FAD) (recall $\theta_{SSR} = 0.2$ and $\theta_{HR} = 1$).

Finally, in the baseline we set the actual and structural price of oil to US$50 per barrel, which is the estimated unconditional mean estimated with data since 1960 (see appendix, figure 5 for details for details). Also, we assume discoveries of 400 million barrels of oil per year in the baseline, equal to the 25th percentile over 1990–2017 (BP-Energy data, see Figure 4.6, panel a).

Calibration to Angola (External-Balance submodel). For the External-Balance submodel, we set the private savings rate and FDI to 19 and 1 percent of GDP, respectively, similar to their averages over the past 20 years. The public investment share in expenditure is set $\eta_t = 0.2$ until 2050 (also the historical average). Finally, we assume that $\overline{b}_t = 0$, which means a balanced budget for the BBR and a structural balance for the SSR. We assume the default private investment crowd-in parameter $\lambda = 0.15$ (Chinn and Ito 2011). For more details of the calibration of the External-Balance submodel refer to appendix, table 4.

[38] We opted to use PWT 8 and the Macro-Fiscal Model Database for 2011 because the new methodology adopted by PWT 9 and PWT 10 implies extremely high capital-to-GDP ratios for Angola. For example, PWT 10 reports a capital-to-GDP ratio of 6 in 2019. This ratio would lead to a remarkably low marginal product of capital in Angola, which is inconsistent with the country's current level of development.

Table 4.3: Baseline Calibration to Angola (Default model): selected parameters, initial conditions, and trajectories of exogenous variables

	Value	Source	Time series
A. Parameters			
Depreciation rate (δ)	4.4%	PWT 10	2000–2019 average
Labor share total (β^{PWT})	0.34	PWT 10	2015–2019 average
Labor share, non-oil (β)	0.56	Calculation	2015–2019 average oil share
Oil rents (γ)	0.33	GTAP	Median oil-exporters 2004–2014
Government:			
Tax rate in oil sector (τ_R)	0.7	IMF-WCE	2001–2013 average
LR public investment ($\bar{x}$)	6→2% of GDI	IMF-FAD	2015–2017 average
MPI (θ)	0.2	IMF-FAD	BBR: 2000–2017 average; SSR ($\theta = 0$); HR ($\theta = 1$)
Sectoral investment elasticity (μ)	1	Assumption	
B. Initial conditions			
Real GDP per capita	US$2,890*	WB-WDI	2020
Exports of oil ($I = 1$)	50.8% of GDP	UN-CT	2007–2015 average
Capital to GDP ratio:	2	PWT/MFMod	2011
Non-oil sector	1	Endogenous	Equalize initial MRPKs
Oil sector	1	Endogenous	Equalize initial MRPKs
Reserves of oil	9.5 Bi/barrels	BP-Energy	2017
Participation rate, *% of working-age population*			
male/female	80.2 / 76.4	WB-WDI	2017
Base year for oil prices	2010		User choice
Initial year of simulation	2020		User choice
C. Trajectory of exogenous variables, 2023–2050			
Price of oil	US$50/barrels	World Bank	Estimated mean 1960–2019
Private investment	20% of GDI	IMF-FAD	2000-2017 average
TFP growth, non-oil sector	1%	PWT 10	Median of LMCs, 2000–2019
TFP growth, oil sector	0%	PWT 10	Median oil exporters, 2000–2019
Human capital growth	0.7%	PWT 10	2000–2019 average
Oil Discoveries			
Baseline & Discovery Shock	400m bbl/year	BP-Energy	25th percentile 1990-2017
Price shock	Endogenous**	Assumption	
Demographics:			
Population growth	3.4→2.3%	ILO	Forecast for 2023–2050
Working-age population	51→59% pop.	ILO	Forecast for 2023–2050
Population, male	49.1% of pop.	ILO	Forecast for 2023–2050
Participation rate (M & F)	≈0 growth	WB-WDI	2000–2019 average

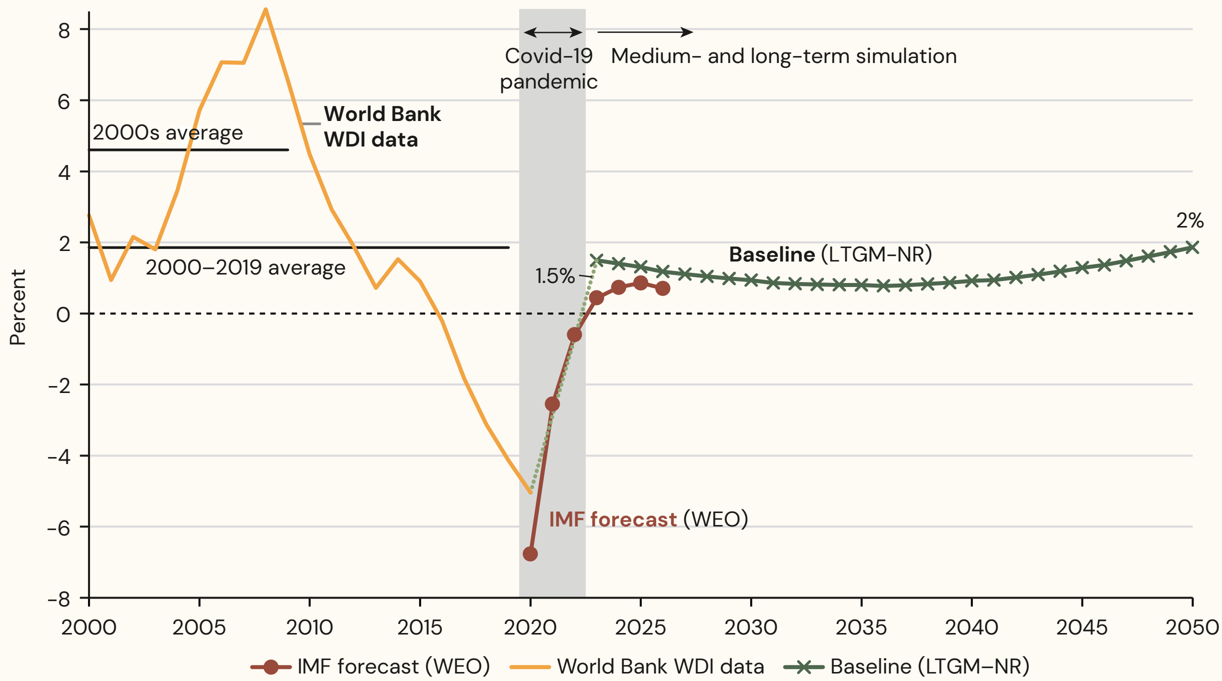
Note: *Real 2010 US dollars. **Discoveries are set to keep reserves constant in per worker terms.

A. Baseline Growth in Angola: LTGM-NR versus Standard LTGM

In this subsection, we: (i) present the baseline GDP per capita growth simulated by the LTGM-NR-default until 2050, (ii) discuss how this baseline is explained by each of the variables of the model, and (iii) illustrate the importance of using a model with a resource sector (by comparing it with a naïve calibration using the standard LTGM).

Baseline. Figure 4.1 shows that under the baseline growth path, Angola's potential GDP per capita growth would slow down from 1.5 percent in 2023 to below 1.0 percent by 2035. After 2035, potential per capita growth would gradually pick up, reaching 2.0 percent by 2050 (green line with crosses). As a result, GDP per capita would increase from US$2,890 in 2020 to US$4,076 in 2050, a cumulative growth of about 40 percent in 30 years.[39] Note that the baseline growth path is slightly more pessimistic than Angola's historical growth over the past two decades and slightly more optimistic than the April 2021 IMF WEO projections for 2023-2026 (IMF 2021). In terms of headline GDP, growth stands close to 5 percent in 2023 (driven by fast population growth) but also displays a U-shaped trajectory, slowing down in the 2030s and picking up in the 2040s (appendix, figure 3, panel A). For more details, see appendix table 2.

Figure 4.1: **LTGM Simulation: Baseline GDP Per Capita Growth in Angola: annual growth rate, percentage**



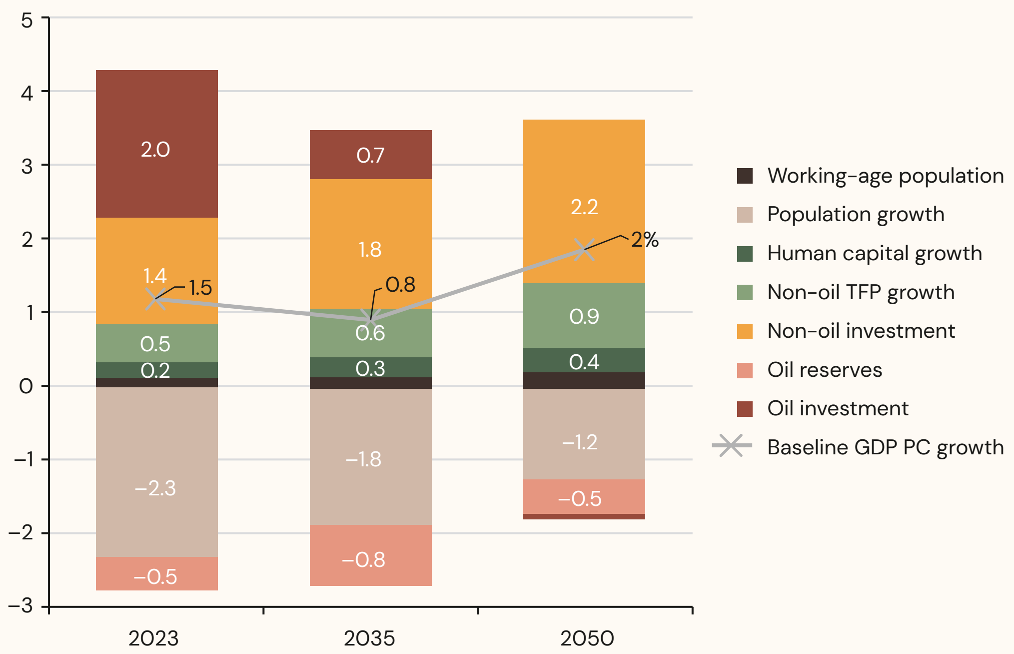
Note: The solid orange line is a five-year moving average of GDP per capita growth in Angola (World Bank WDI).

[39] All monetary values are expressed in constant 2010 U.S. dollars.

Growth decomposition. To shed light on the U-shaped dynamics of baseline growth, Figure 4.2 decomposes the contribution of each macro variable for GDP per capita growth in 2023 (initial year of the simulation), 2035 (minimum point for growth), and 2050 (last year).[40] The decomposition shows that the drivers of growth change over time. In 2023, growth is mainly driven by capital accumulation, with total investment generating 3.4 percentage points (ppts) of growth. High population growth and depleting reserves of oil push growth down by 2.3 and 0.5ppts, respectively. Non-oil TFP and human capital have only a moderate contribution to growth of 0.7ppts.

The decomposition for 2035 suggests that the decline in the oil sector is the main reason for the 2023–2035 slowdown—the combined contribution to growth from oil investment and oil reserves falls from +1.5ppts in 2023 to –0.1ppts in 2035. Appendix, figure 3 shows that while GDP per capita grows steadily at 3 percent in the non-oil sector, it falls sharply in the oil sector (panel b). This decline is mainly driven by depleting oil reserves, projected to halve by 2035 (panel c). Depleting oil reserves reduces oil output directly but also disincentivizes investment in the sector, reinforcing the initial contraction (panel d).

Figure 4.2: Year-by-Year Decomposition of Baseline GDP Per Capita Growth: contribution of each macro variable to growth, percentage points



[40] The growth decomposition captures the proximate determinants of growth only—for example, the induced effect of TFP on investment is attributed to the latter, not the former. It is carried out period-by-period by a linear approximation of the effect of each variable on GDP per capita, as in the following expression: *Contribution of X to GDP per capita growth in t*

$$\equiv \frac{\partial_X GDPPC_t \; \Delta X_t}{GDP_t} = \left(\frac{GDP_t^0}{GDP_t}\right)\partial_X GDP_t^0 \;\; \Delta X_t + \left(1-\frac{GDP_t^0}{GDP_t}\right)\partial_X GDP_t^{oil} \;\; \Delta X_t$$

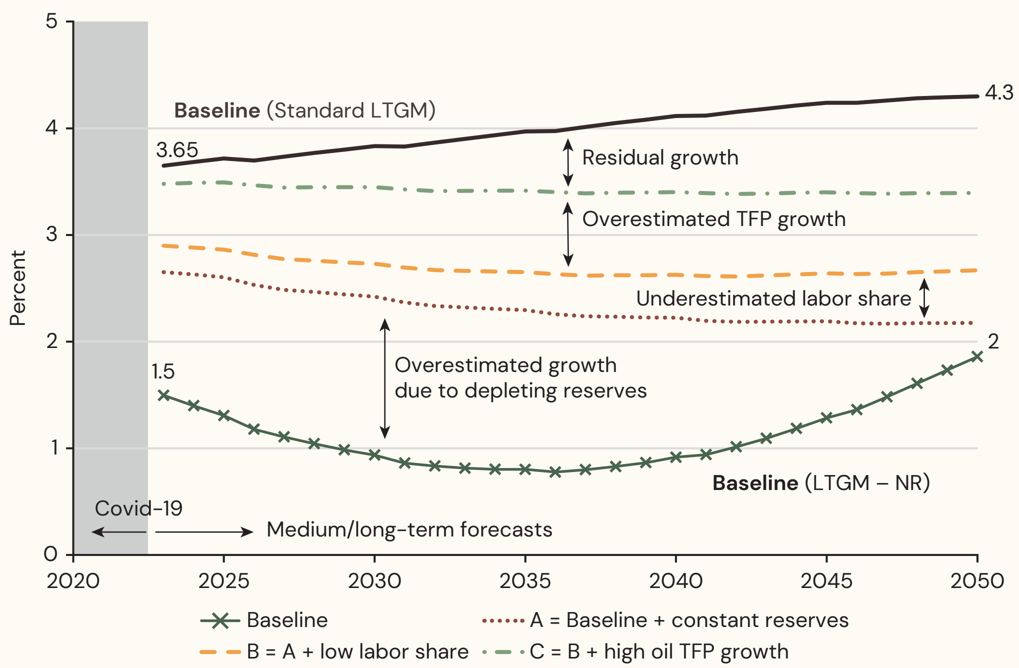
For example, GDP per capita in Angola is given by $DPPC_t = GDPPC_t^0 + GDPPC_t^{oil} = A_t^0(h_t\omega_t\varrho_t N_t)^{\beta}(K_{t-1}^0)^{1-\beta} / N_t + p_0^{oil}Q_t^{oil} / N_t$.
In this case, the contribution of population growth to GDP per capita growth in period t is given by the following simple expression: $\frac{\partial_N GDPPC_t}{GDP_t}\Delta N_t = \left(-(1-\beta)\frac{GDP_t^0}{GDP_t} - 1\frac{GDP_t^{oil}}{GDP_t}\right)\frac{\Delta N_t}{N_t} = -\left(1-\beta\frac{GDP_t^0}{GDP_t}\right)\%\Delta N_t$

Finally, the decomposition shows that the recovery after 2035 is explained by an improvement in demographic trends and a switch of the economy toward the non-oil sector, which has better fundamentals. More specifically, population growth declines substantially, mitigating the negative impact on per capita growth to –1.2ppts (up from –1.8ppts in 2035). In addition, the depletion of reserves (and lack of oil productivity growth) leads gross investment in the oil sector to fall to nearly zero in the long term. As a result, investment in the non-oil sector increases substantially over time, accounting for 2.2ppts of growth in 2050 (versus 1.4ppts in 2023). Moreover, as the non-oil sector accounts for an increasingly large share of the economy, non-oil TFP and human capital increase their contribution to growth: in 2050, they jointly generate 1.3ppts of growth (up from 0.7ppts in 2023).

LTGM-NR versus standard LTGM. To illustrate the importance of accounting for sectoral heterogeneity in large resource-rich countries, we compare the baseline growth path implied by the LTGM-NR with the standard "one-sector" LTGM. We produce a naïve calibration of the standard LTGM to be consistent with the LTGM-NR at the aggregate level. Except for the labor share and TFP growth, which are discussed below, the calibration of the two models is essentially the same (see appendix, table 5 for a full description). It should be noted, however, that an adjusted calibration of the standard LTGM tracks growth very well in the non-resource sector from the LTGM-NR.[41]

Figure 4.3 shows a large difference between the two models, with the naïve calibration of the standard LTGM (solid black line) being substantially more optimistic than the NR extension (green line with crosses).

Figure 4.3: Baseline Growth Simulation: LTGM-NR Versus Standard LTGM (naïve calibration): GDP per capita, Percent annual growth rate



Notes: Counterfactual A is equal to baseline but with reserves of oil constant over time in per worker terms. Counterfactual B is equal to A but with a labor share of 0.34. Counterfactual C is equal to B but with 1 percent oil TFP growth.

[41] The only adjustment required is to scale up the labor share in the standard LTGM to $\beta = \beta^{PWT} \times GDP_t / GDP_t^0$. In this case, the standard LTGM captures almost perfectly non-oil growth in the LTGM-NR (see appendix, figure 6).

Baseline GDP per capita growth under the standard LTGM starts at 3.7 percent in 2023 and accelerates to 4.3 by 2050. That speedy growth trajectory is in sharp contrast with the IMF medium-term projections or the recent growth history in Angola.[42]

A combination of three factors explains the "excess" growth implied by the standard LTGM.[43] First, and quantitatively the most important, the standard LTGM does not account for depleting oil reserves. To assess the magnitude of this effect, we run counterfactual "A" with the baseline LTGM-NR but keeping reserves of oil constant over time.[44] The vertical distance between the baseline and counterfactual A shows the excess growth generated by not accounting for depleting reserves. The extra growth averages 1.1ppts over 2023–2050 but shrinks over time as the oil sector becomes less important as a share of GDP (see appendix, table 3 for details).

Second, the Standard LTGM naïve calibration distorts the impact of growth fundamentals by ignoring the heterogeneity in the labor share across sectors. In the standard LTGM, we set $\beta = 0.34$ to match the labor compensation share in total income from PWT. This particularly low aggregate labor share is the outcome of an economy highly dependent on oil, which is typically a capital-intensive industry.[45] The LTGM-NR specification is more suitable for large oil producers as it allows the user to choose the labor share specific to the non-oil sector. Recall that in the baseline we set $\beta = 0.56$, which is a more conventional value for this parameter—see appendix, figure 4—but also consistent with the aggregate labor share from PWT (0.56 x initial non-oil share in GDI = 0.34).

The "distorted" low labor share in the naïve calibration of the standard LTGM boosts the effect of investment in physical capital on growth. As physical capital is reproducible, this makes growth much easier. In the limit where the labor share is zero, the standard LTGM becomes an "AK" model that delivers perpetual endogenous growth. To assess the net effect of the low labor share on growth, we run counterfactual B: equals counterfactual A (baseline + constant reserves) but with the labor share lowered to 0.34 (as in the standard LTGM). Not surprisingly, as investment is the main driver in Angola, the net effect is positive and substantial: the distorted labor share leads to an extra 0.5ppts of growth on average (as shown by the vertical distance between the dotted and dashed lines).

Third, in the naïve calibration of the standard LTGM we set *aggregate* TFP growth to 1 percent to match the average in lower-middle-income countries over the past two decades. However, there is large heterogeneity in TFP growth across sectors. Recall that in the LTGM-NR we set TFP growth in the *non-oil sector* to 1 percent but, based on evidence from large oil exporters, we assume no TFP gains in the oil sector (see appendix, figure 2). To assess the effect of overestimated TFP growth rates, we run counterfactual D: equals counterfactual C (baseline with constant reserves and low labor share) but with 1 percent oil TFP growth, so aggregate TFP is also 1 percent, as in the standard LTGM. The excessive TFP growth leads to an extra 0.6ppts of growth on average over 2023–2050.

[42] Although Angola reported comparably high growth rates in the 2000s, this growth was related to developments in the oil sector, which is a channel not built-in the standard LTGM. For more details of baseline growth in the standard LTGM, see a growth decomposition in appendix, figure 7.

[43] The remaining gap between the models is related to factors that are difficult to shut down for analytical purposes, such as the structural differences between the production functions.

[44] In fact, we keep reserves of oil constant *in per worker terms,* which implies that labor productivity does not fall over time due to depleting oil reserves.

[45] Appendix Figure 4 shows that Angola reported the lowest average labor share over 2000–2019 among LMCs (PWT 10). It also shows that large oil exporters tend to have low labor shares, which is in line with the empirical evidence of low labor shares in resource industries (see Lebdioui 2021).

B. The Effects of Oil Price Shocks in Angola

In this section, we assess the effects of oil prices on Angola's long-term growth. Note that oil prices shocks have potentially very large effects on short–medium run growth through Keynesian mechanisms. However, those mechanisms are not part of neoclassical growth models like the LTGM-NR, and while important, are not considered here. Moreover, it can be the case that the best fiscal rule for long-run growth produces excessive volatility in the medium term.

More specifically, we consider a 10-year boom-and-bust cycle, in which the price of oil increases from US$50 to US$80/barrel from 2025 to 2030 and then returns to US$50 by 2035, remaining at that level thereafter (see Figure 4, panel a). This scenario is assessed relative to the baseline oil price of US$50 until 2050. We also set US$50/barrel as the reference price to determine structural revenues.[46] To isolate the price effect, we assume that oil reserves are held constant in per worker terms by setting discoveries equal to production (both in per worker terms), and the structural production of oil is set equal to actual production.

In this section, most variables are expressed as deviation from the baseline. For example, panel b of Figure 4.4 displays incremental GDI as a percent of baseline GDI, defined as: 100 × [(Scenario real GDI in US$)/(Baseline real GDI in US$) – 1]

Each line represents the simulation of GDI under a specific fiscal rule (BBR, SSR, BBR-HR, and SSR-HR) and submodel (Default and External-Balance). Likewise, panels c, e, and f display incremental GDP, and public and private investment, respectively. Finally, panel d shows incremental GDP growth, defined as the difference in growth rates between scenario and baseline, in percentage points. Below we briefly discuss the impact of oil prices in each variable. Appendix, table 6 through appendix, table 8 provide a detailed summary of the results.

Impact on GDI. The first thing to notice is that, under any specification, the oil price shock leads to large increases in GDI of around 25%–35% (see Figure 4.4, panel b). Around 25ppts of this increase is mechanical: oil accounts for around 40 percent of GDI at the start of the simulation, and at the peak, the oil price increases 60 percent (= $80/$50-1), with 40% × 60% ≈ 25%. The excess (depending on the submodel and fiscal rule) is due to (i) reallocation of capital toward the oil sector (which is more productive in dollar terms), and (ii) higher investment. Of course, when the oil price falls over 2030–2035, the effect goes into reverse, and GDI falls sharply.

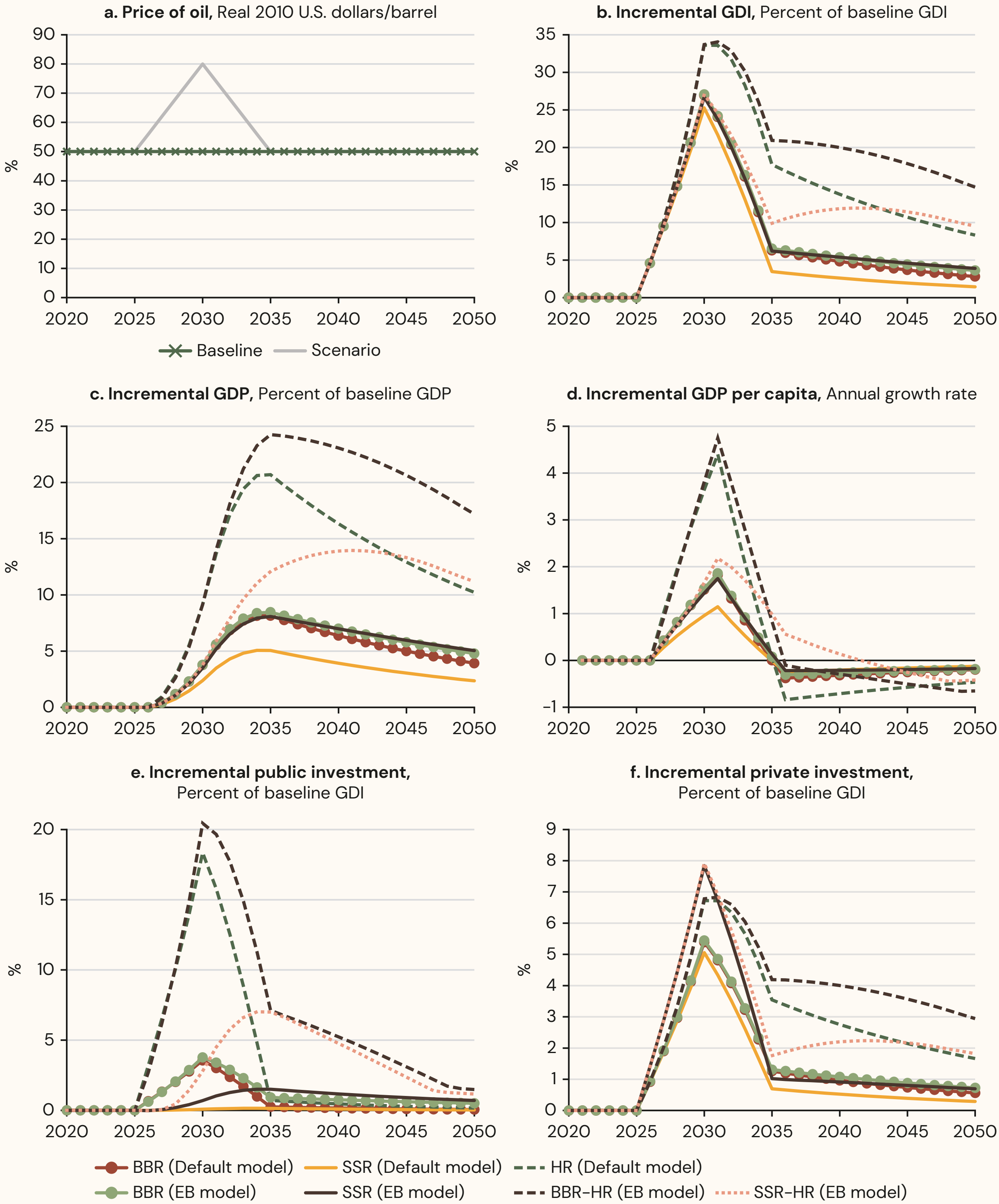
The paths for different fiscal rules fall into two groups. First, the HR in the Default and BBR-HR in External-Balance models have the largest increase in GDI, hitting around 35 percent above baseline in the early-2030s. This is because the vast majority of commodity revenues are spent on public investment. The second group contains all the other rules: BBR, SSR, and SSR-HR. As discussed below, these rules lead to much smaller increases in investment.

Impact on GDP. In the very short run, the effect of the oil price shock on the level of real GDP is zero because commodity prices do not directly affect GDP (Figure 4.4, panel c): for example, by 2026, real GDP is the same as in the baseline, even though oil prices are $6/barrel higher. Instead, GDP only increases after a few years when the productive capacity of the economy expands through higher investment. The flipside of the muted increase in real GDP is the muted *decrease* in GDP when oil prices fall: whereas real GDI (relative to baseline) falls sharply, most measures of GDP only fall slightly and with a delay.[47] The rules that

[46] These assumptions are based on the estimated forecast distribution of oil prices, using the World Bank's Commodity Markets Outlook data from 1960 to 2019. The price of US$80 is the 75th percentile of the distribution and US$50 is the unconditional mean. See appendix, figure 5 for details.

[47] Note that in reality, large movements in aggregate demand associated with the commodity price shock will cause disruption to

Figure 4.4: The Effects of Oil Price Shocks in Angola: Comparison between different fiscal rules and LTGM-NR models (incremental = scenario – baseline)



generate a larger increase in GDP are the ones with the higher GDI in panel b: BBR-HR in both models, with peak GDP about 20–25ppts above the baseline in 2035 (which is five years after the peak oil price). In contrast, the BBR and SSR have a smaller boost to GDP, with a peak of 5–10ppts above the baseline in 2035. The SSR-HR in the Extended Balance submodel generates a boost to GDP that is more sustainable and lasts well beyond the duration of the price cycle. Moreover, the SSR-HR outperforms the BBR-HR (Default model) in the long run.

While the different rules do have a differential effect on GDP growth rates, it is perhaps less than might be expected (see Figure 4.4, panel d). The peak increment to real GDP growth (relative to the baseline) is about 5ppts in 2030 in the BBR-HR (for both submodels). In contrast, the other rules lead to a peak increase in GDP growth of only about 1–2 ppts in 2030—despite a large increase in government revenue (discussed below). Perhaps surprisingly, the increment to real GDP growth continues to be positive as oil prices fall over 2030–2035, and only turns negative after 2035. For the SSR-HR, incremental GDP growth remains positive until 2042.[48] Another surprising result is that the BBR and SSR yield almost exactly the same growth path in the External-Balance submodel. As we will discuss below, under this calibration with $\eta = 0.2$ and $\lambda = 0.15$ it does not make a large difference if oil revenues are saved or spent under these two rules: each extra dollar of oil revenue becomes 20c of public investment if spent; or 15c of private investment if saved.

Impact on public investment. The oil price shock triggers GDP growth, mostly because it leads to higher public investment. In the Default submodel, the increase in public investment as a share of baseline GDI is approximately $\theta\Delta z_t$ (the marginal propensity to invest times the change in revenues). As oil revenues account for almost 30 percent of GDI in 2020 ($\tau_R y_{2020}^{oil} = 0.7 \times 0.4$), a 60 percent increase in oil prices would boost revenues by nearly 20 percent of baseline GDI (see appendix, figure 8, Panel A). Under the SSR $\theta = 0$, so public investment is unchanged, which is shown by the yellow line in Figure 4.4, panel e. In the BBR-HR, $\theta = 1$, so all the additional revenues are spent, leading to an increase in public investment by around 20 percent of baseline GDI at the peak, as shown by the green dashed line. Finally, under a BBR $\theta = 0.2$, so 20 cents in the dollar windfall oil revenue is invested, yielding an increase in public investment of about 4 percent of baseline GDI (maroon circled line). In all cases, public investment nearly returns to baseline levels after the end of the price cycle in 2035. This feature stems from the assumption that structural production of oil equals actual production, implying that $\theta\left(z_t^R - \tilde{z}_t^R\right) = \theta\left(P_t^{oil} - \$50\right)Q_t^{oil} = 0$ for all θ after 2035 as P_t^{oil} returns to US$50 (equation (13)).

In the External-Balance submodel, the paths for public investment under the BBR and SSR are fairly similar to their Default submodel counterparts. However, the deviations of BBR-HR and SSR-HR are worth noting, as they both lead to persistently higher public investment, though for different reasons.

Under the BBR-HR, the oil sector expands rapidly during the oil price cycle, generating higher oil revenues that are reinvested under the BBR-HR. Though this effect is present in other simulations, it is especially strong for the BBR-HR. For example, in 2035, incremental revenues stand at 10 ppts of baseline GDP under the BBR-HR, more than double the value generated by the BBR or SSR (see appendix, table 6 and appendix, figure 8).

The SSR-HR (pink dotted line) generates high public investment for many years after the end of the oil cycle (extra 5ppts on average in 2036–2050, see appendix, table 8). This is because the extra interest savings from paying down government debt are recycled into the budget, releasing extra resources for higher public investment (for details, see appendix, figure 8).

domestic non-traded goods production. But these demand-side effects are not in this type of neoclassical model.

[48] The reason is that oil prices have no direct effect on real GDP—only an indirect effect via investment, which continues to be elevated as long as oil prices are above their steady-state level.

Impact on private investment and spillovers. Private investment increases in all simulations, though they can be much larger in the External-Balance submodel than the Default submodel. In the Default submodel, private investment is 20 percent of GDI, so as GDI increases by 25–40 percent, private investment increases by 5–8ppts of baseline GDI (Figure 4.4, panel f). In the External-Balance model we assume that if the public sector runs a surplus of one dollar, this will free up λ dollars for private investment. However, it is only the SSR and SSR-HR that generate substantial changes in the budget balance, and hence it is only these two rules that feature larger increases in private investment with $\lambda > 0$.[49] With our default calibration of $\lambda = 0.15$, private investment increases further to peak at 8ppts above baseline by 2030 in the SSR and SSR-HR.

The combined effect of higher public and private investment provides a strong engine of growth in Angola because of the low initial capital-to-output ratio (2), which makes GDP growth sensitive to investment rates.

Extension: a higher investment crowd-in λ parameter. Now we discuss an alternative parametrization with a higher level of crowding-in of private investments, $\lambda = 1$ (up from the default of $\lambda = 0.15$). When $\lambda = 1$, the current account balance is effectively fixed as a share of GDI. As private savings and FDI are also assumed to be fixed shares of GDI, then an extra dollar of fiscal surplus ends up funding an extra dollar of private investment (up from 15 cents in the baseline).[50]

This calibration has little effect on BBR and BBR-HR rules, because they generate no additional fiscal surplus, but allows the SSR and SSR-HR rules to generate much higher investment and growth rates. One can see this on panel a of Figure 4.5, where private investment increases by 25ppts of baseline GDI for the SSRs with $\lambda = 1$ in 2030, rather than 8ppts in the simulations with the default calibration of $\lambda = 0.15$. This means the path for GDI with either SSR in the External-Balance submodel is now similar to the BBR-HR (Figure 4.5, panel b), achieving a 35ppt increase in GDI by 2030 (though through higher private rather than public investment). Moreover, the SSR-HR achieves the highest growth path—also peaks at 35ppts of baseline GDI in 2030—but outperforms the other rules in the longer term. Finally, note that different from the default calibration, the BBR and SSR yield very different trajectories with $\lambda = 1$.

C. The Effects of a Large Discovery of Oil in Angola

In this section, we assess the effects of a large discovery of oil in Angola. Specifically, we assume a discovery of 2.7 billion barrels of oil in 2025, calibrated to match the 2002 discovery, which was the largest over the last 30 years. In all other years, as in the baseline, we assume discoveries of 400 million barrels, equal to the 25th percentile of the distribution over 1990–2017 (see Figure 4.6, panel a).

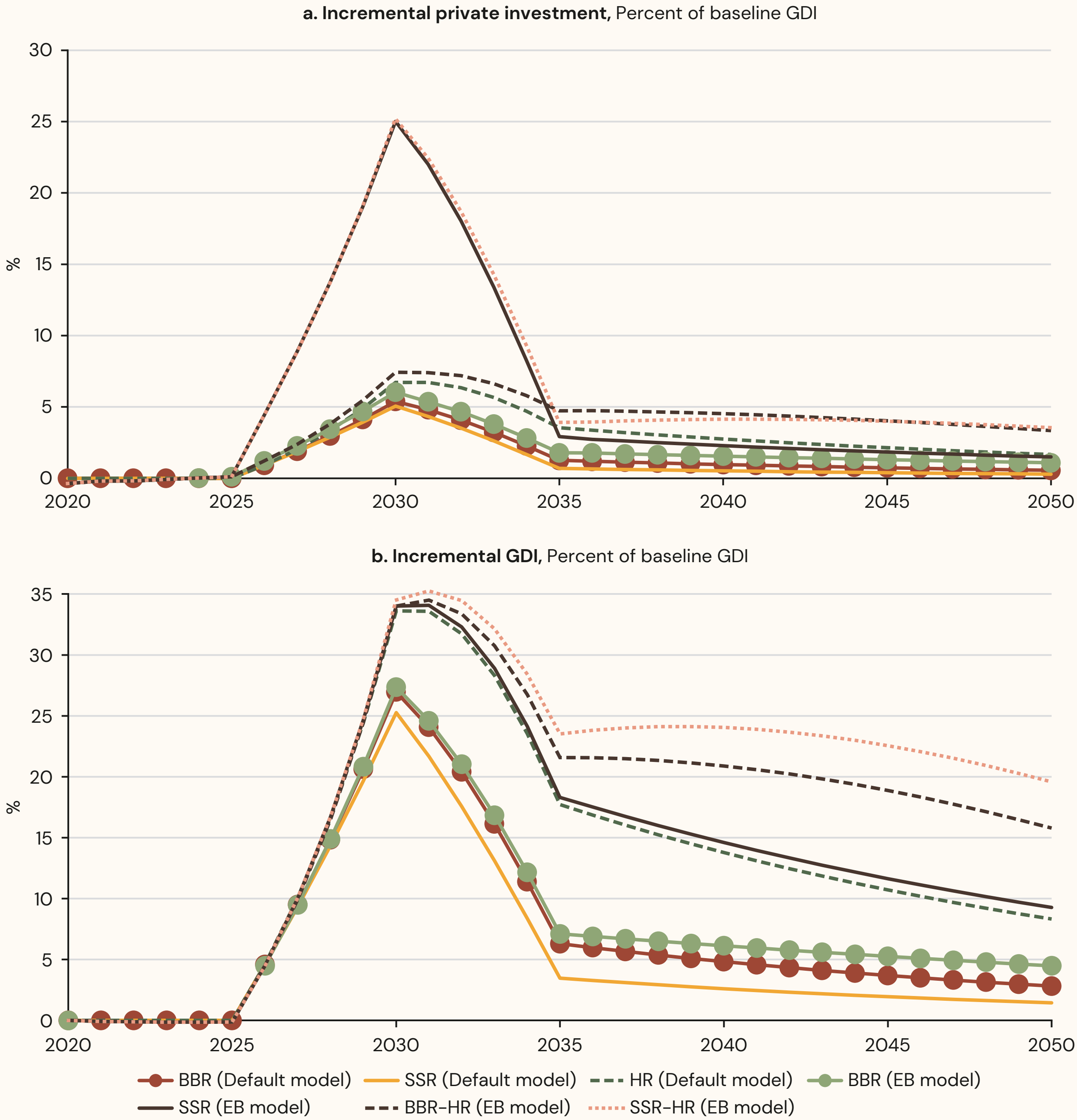
Note that in reality, discoveries often become useable “reserves” over a period of many years. While we assume an immediate transition here for analytical purposes—to clarify the effect of the shock—we advise that users of the LTGM-NR smooth the discovery over several years.

To isolate the effect of the 2025 discovery, we assume constant oil prices at US$50/barrel, as in the baseline. This last assumption means that real GDI and real GDP—which had large differences in section B—will have similar growth profiles, so in this subsection we only report results for GDP. Finally, to allow the

[49] Under the BBR the budget is balanced, so there is almost no increase in the fiscal surplus. In practice there is sometimes a small increase in fiscal savings, because the BBR is specified as a share of GDI, which increases with an oil price shock.

[50] In practice, the extra private investment could be supplied by a reduction of credit rationing and easing of loan conditions or lower interest rates when domestic banks no longer purchase so many government bonds (though we do not model this). The calibration also applies most effectively to countries with very closed current accounts. In contrast, a small λ is more appropriate for countries open to capital flows.

Figure 4.5: The Effects of Oil Price Shocks in Angola: High private investment crowd-in ($\lambda = 1$) (fixed CAB as share of GDI)

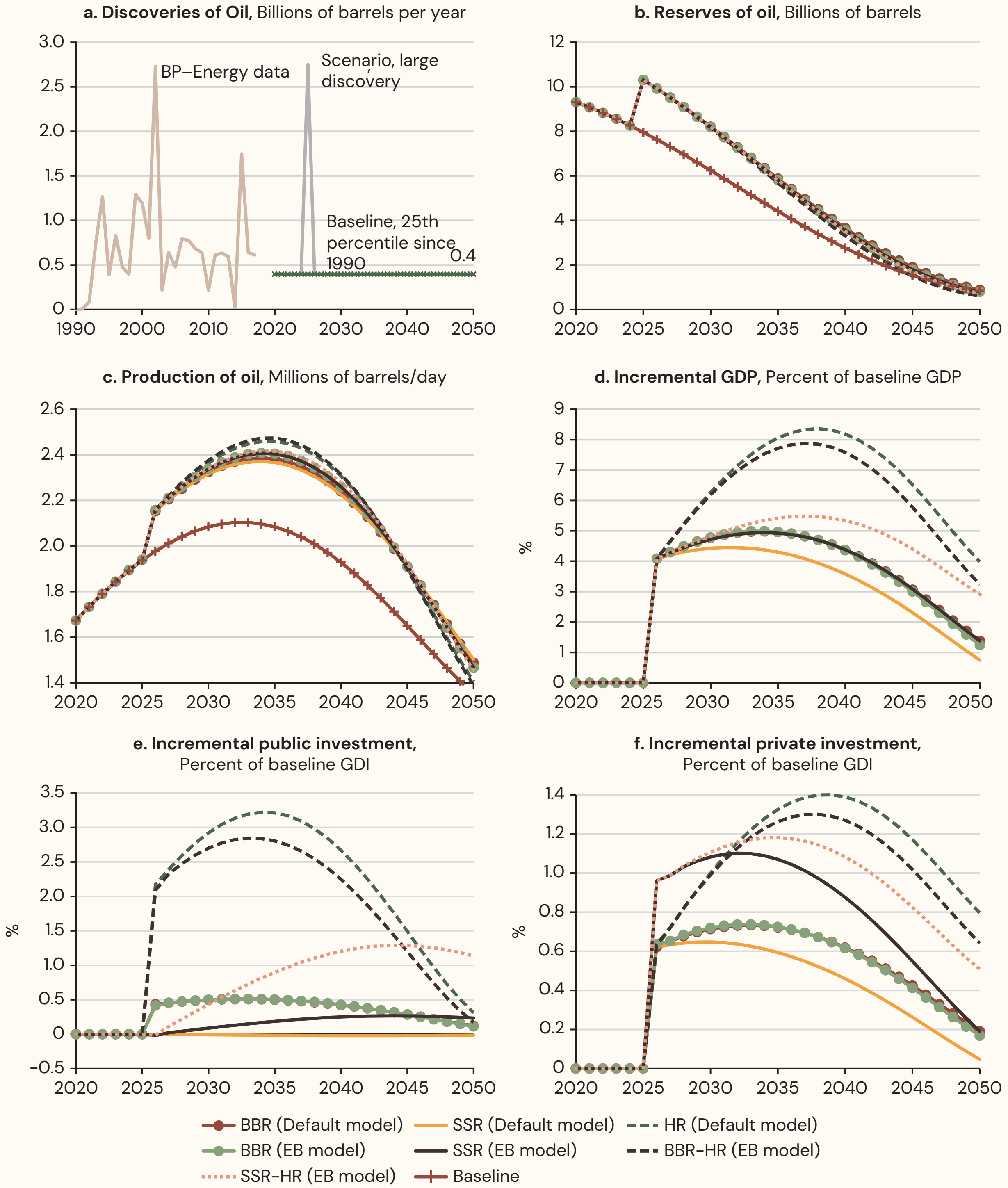


discovery shock to generate cyclical oil revenues—and, hence, different spending profiles across fiscal rules—we set structural (long run) oil production equal to the baseline oil production.[51]

The first-order effect of an oil discovery is to increase reserves and, hence, production: a 1 percent increase in reserves leads to $\gamma = 1/3$ percent increase in oil production (see equation (2)). Panel b of Figure 4.6 shows

[51] Note that this assumption is different from section IV.B, where structural production of oil was set equal to actual production. That assumption was designed to isolate the effect of oil price shocks on the government spending profile. However, we now want to explore the effects of higher oil output across different fiscal rules, keeping oil prices constant. This can be done assuming that structural production is equalto the baseline, although similar results would be achieved by assuming that structural production follows an N-year moving average of actual production.

Figure 4.6: The effects of oil discoveries in Angola: Comparison between different fiscal rules and LTGM-NR models* (incremental = scenario – baseline)



that the 2025 discovery raises oil reserves from 8 billion to 10 billion barrels, a 25 percent increase relative to the baseline. In 2026, higher reserves boost oil production to nearly 2.2 million barrels per day, a 9 percent increase relative to baseline ($\approx \gamma \times \%\Delta R^{oil}_{2025}$, see panel c) in almost all models. As oil accounts for about one-half of Angola's economy, the increase in oil production boosts total GDP by about four percentage points in 2026 (see panel d).

After 2026, the impact on growth depends mostly on public investment, which, in turn, depends on how the government spends/saves the windfall revenue generated by the discovery (figure 4.6, panel e). The shock leads to extra revenues of 2–3 percent of baseline GDI until 2040 but declines sharply after that due to depleting oil reserves (see Appendix Figure 9).[52] This path is very similar across models and rules, except from the BBR-HR, which generate higher growth and, hence, higher oil revenues in the 2030s.

The BBR-HRs (both models) are the only rules that yield a faster growth rate for several years after the discovery shock. As above, the BBR-HRs invest all windfall oil revenue, which increases GDP growth (oil and non-oil) and private investment in relation to the baseline.[53] In contrast, the simple BBRs (either model), invest only 20 percent of the windfall, leading to a modest impact on growth after 2026.

The SSRs also generate a relatively small boost to public investment and long-term growth because the extra revenues are mostly classified as cyclical and so are saved. The SSR in the Default submodel generates the lowest growth path after 2026 as public investment remains constant and private investment increases only modestly in relation to the baseline. As above, the SSRs in the External-Balance submodel also generate a small amount of crowding-in of private investment (15 cents per dollar of fiscal surplus, see figure 4.6, panel f).

Over the long term, the differences in public and private investment accumulate to modest differences in the capital stock and GDP across the different fiscal rules. In the BBR-HRs (both submodels), GDP is about 8 percent above baseline by 2040, which is double the mechanical increase in 2026 (see figure 4.6, panel d). However, by 2040, GDP under the non-HRs are similar to the initial shock in 2026 of 4 ppts above baseline (variation 3.5–4.5ppts, depending on the rule). Finally, as above, the SSR-HR recycles interest savings into higher public investment. While the increase in investment (public and private) does boost the productive capacity of the economy under these rules, a higher rate of extraction reduces reserves, which is roughly offsetting. Consequently, by 2040 around 75% of the initial discovery has been depleted (see panel b). See appendix, table 9 and appendix, table 10 for further details.

5. Conclusion

This chapter develops the Natural Resource extension of the World Bank's Long Term Growth Model (LTGM-NR), which evaluates the effects of commodity price shocks and discoveries of natural resources on medium- and long-term growth in resource-rich economies. The LTGM-NR augments a relatively standard neoclassical model (the LTGM) by adding a resource sector and a government whose fiscal rule determines how to spend or save resource revenues. The model is designed to be simple enough so that its mechanisms are clearly understood, and its solution can be implemented in a spreadsheet (without macros). The accompanying toolkit is preloaded with data for 56 commodity-rich economies and 11 resource industries and can be adjusted to the needs of users.

In a calibrated version of the model to Angola, we find that population growth, depleting oil reserves, and a reallocation of the economy toward the non-oil sector leads to a medium-term growth slowdown and subsequent recovery in the long term. This nonlinearity is difficult to capture in standard one-sector

[52] For example, in 2026, oil revenues increased by just above 2 percent of baseline GDI: a 9% increase in oil production x 35% oil as share of total GDI in 2025 x 70% oil tax rate.

[53] Recall that private investment increases in absolute terms because it is a fixed fraction of GDI, which increases relative to baseline after 2025 due to the discovery.

neoclassical models. Failing to account for sectoral heterogeneity, naïve calibrations could lead to large differences in growth projections.

Next, we find that an increase in commodity prices can substantially affect real income (real GDI), though only while prices remain elevated. In contrast, the effect on real GDP is smaller and delayed because only the increase in the volume of production is counted (not the price effect). The boost to GDP is more persistent—outlasting the price boom—but its size depends on the government fiscal rule. Not surprisingly, Hartwick rules that invest all extra resource revenues generate the largest increase in GDP. Structural surplus rules (SSRs) can potentially yield large growth rates in countries where higher public surpluses crowd in private investment. However, in our default calibration for Angola, the crowd-in is small, and so SSRs perform similarly to balanced budget rules where the fraction of extra spending on public investment is equal to the historical average.

In contrast to price shocks, when resource discoveries become available for production, there is the same immediate boost to GDP and GDI. The size of the gain largely depends on the share of resource rents in resource production. The subsequent evolution of GDP depends on the fiscal rules in a similar way to price shocks.

In closing, it is important to mention several caveats. First, the LTGM-NR is a simple neoclassical growth model and so omits some mechanisms connecting the commodity sector and growth that are outside this framework. Most important is the lack of an aggregate demand side, which means there is no stimulatory effect of extra commodity-related spending on the local economy in the short run. Our model also lacks channels through which commodity wealth might reduce long-term growth, such as Dutch Disease or a growth-sapping political economy.

Second, governments may have many different objectives in designing fiscal rules governing the use of resource revenues, beyond long-term growth. Other objectives include intergenerational equity (particularly in countries with limited reserves), consumption smoothing, and reducing business-cycle volatility. Often these objectives are conflicting. For example, our rule that delivers the fastest long-term growth (a Hartwick rule) can also result in procyclical spending that exacerbates the business cycle in the short term. As such, the findings in this chapter regarding the ranking of different rules reflect only one dimension of performance —medium and long-term growth— and are not a blanket recommendation.

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Chapter 5

Malaysia's Economic Growth and Transition to High Income: An Application of the World Bank Long Term Growth Model (LTGM)[1]

Sharmila Devadas, Jorge Guzman, Young Eun Kim, Norman V.Loayza and Steven Pennings[2]

Abstract

This chapter studies economic growth in Malaysia, with the purpose of assessing the potential to attain the status and characteristics of a high-income country. Future economic growth is simulated under a business-as-usual baseline, where the growth drivers follow their historical or recent trends, and under different scenarios of reform, using the World Bank Long Term Growth Model (LTGM). Under the business-as-usual baseline, Malaysia's gross domestic product (GDP) growth is expected to decline from 4.5 to 2.0 percent over the next three decades, following the country's transition to high income in 2024 (which might be delayed due to the effects of COVID-19). This decline is partly due to demographics, but also a declining marginal product of private capital and slowing growth rates of total factor productivity (TFP) and human capital. Strong reforms are required for Malaysia to grow beyond what is expected based on historical trends, especially for human capital, female labor force participation, and total factor productivity. In the strong reform scenario, based on growth drivers achieving a target corresponding to the 75th percentile of high-income countries, GDP growth is expected to have a substantially higher trajectory, reaching 3.6 percent by 2050.

JEL: D24, G14, G18, H54, I15, I25, J16, O16, O33, 043, 053.
Keywords: Economic growth, human capital, investment, labor force participation, total factor productivity, innovation, education, market efficiency, infrastructure, institutions, Malaysia.

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[1] **Editors' note:** This chapter is a reprint of World Bank Policy Research Working Paper WPS 9278, originally published in June 2020. The appendices are available in the working paper version at the Long Term Growth Model website: https://www.worldbank.org/LTGM. Sharmila and Jorge's affiliations are based on when the article was written.

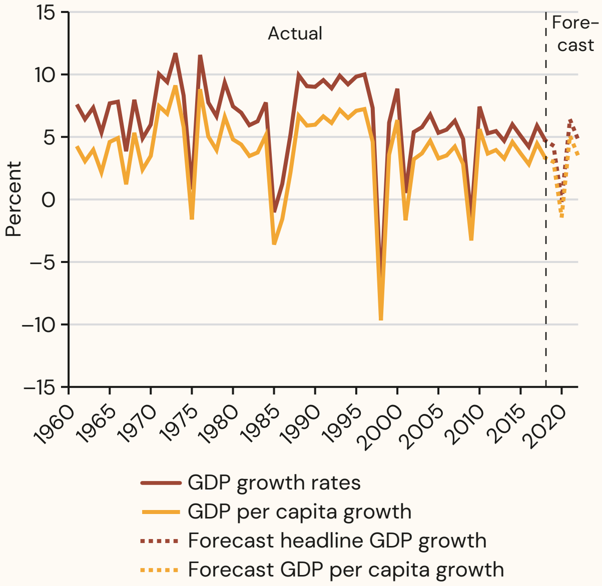
[2] Sharmila Devadas, Jorge Guzman, Young Eun Kim, Norman V.Loayza and Steven Pennings, World Bank. Corresponding author email: spennings@worldbank.org. The views expressed here are the authors', and do not necessarily reflect those of the World Bank, its Executive Directors, or the countries they represent. We appreciate comments from Yew Keat Chong, Firas Raad, Richard Record, Shakira Binti Teh Sharifuddin, and seminar participants at the World Bank. To download the Long Term Growth Model spreadsheets, visit https://www.worldbank.org/LTGM

1. Introduction

Over the past few decades, Malaysia has recorded strong and sustained growth, apart from during periods such as the Asian financial crisis in 1997, the global financial crisis in 2019 and—more recently—the COVID-19 pandemic in 2020 (figure 5.1). As the economic effects of the COVID-19 pandemic will hopefully be short lived, this chapter looks through the current growth volatility to focus on long-run trends. Malaysia's long-run growth performance has supported remarkable gains in social and economic development, with a ninefold increase in per capita income over the last seven decades. The country is expecting to transition to high-income status in the near future (figure 5.2), where high income is based on the World Bank's cross-country classification. This chapter studies Malaysia's long-run economic growth prospects as it attains the status and characteristics of a high-income economy.

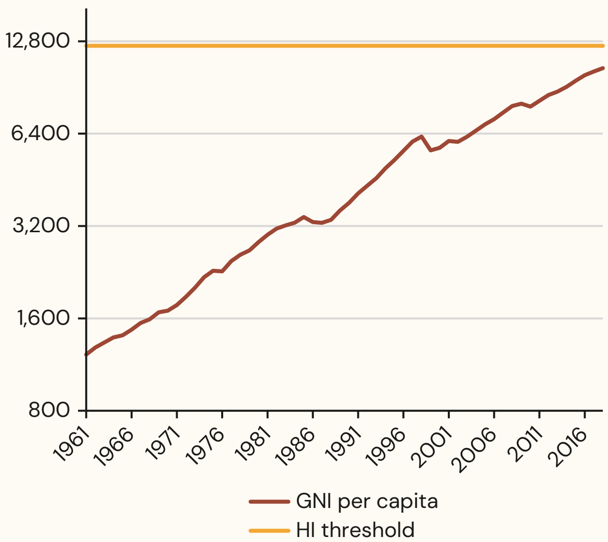
The government of Malaysia's long-run and medium-run growth strategies are outlined in its Shared Prosperity Vision (SPV) 2030 and 12th Malaysia Plan (respectively). The SPV and Malaysia Plan go beyond high-income status, also ensuring growth is both sustainable and equitable. The October 2019 SPV sets out "a commitment to make Malaysia a nation that achieves sustainable growth along with fair and equitable distribution."[4] The SPV blueprint proposes targets across key growth areas: regional inclusion, the role of the small and medium enterprises (SMEs), human capital, labor market and workers' compensation, and social capital and well-being. The 12th Malaysia Plan, the next five-year national development plan, is slated for 2021–2025. It aims to be aligned to SPV 2030, covering the areas of economic empowerment (growth drivers and enablers), environmental sustainability, and social re-engineering (essentially improving the well-being of the people and social cohesion).

Figure 5.1: Historical GDP Growth



Source: WDI. Codes: NY.GDP.MKTP.KD.ZG, NY.GDP.PCAP.KD.ZG & EAP Economic Update April 2020.

Figure 5.2: Historical Real GNI Per Capita Level[3]



Source: WDI. Codes: NY.GNP.PCAP.CD & NY.GNP.PCAP.KD.ZG.

[3] Methodology for figure 5.2: Calibrate the levels to GNI per capita Atlas method (NY.GNP.PCAP.CD) for 2018, and then cast backwards using real GNI growth (NY.GNP.PCAP.KD.ZG). Horizontal orange line shown is the 2019–2020 high-income threshold.

[4] The new government that assumed administration at the end of February 2020 has pledged to ensure the continuity of SPV 2030.

This chapter simulates Malaysia's long-run growth prospects using the World Bank Long Term Growth Model (LTGM), a suite of spreadsheet-based tools building on the celebrated Solow-Swan growth model. The Long Term Growth Model—Public Capital Extension (LTGM-PC) is used as the base model (Devadas and Pennings 2019 and also chapter 2 in this volume), which allows for private and public investment to have different effects on growth. Human capital and TFP growth are endogenized using LTGM's Human Capital extension (LTGM-HC) and TFP extension (LTGM-TFP) (Kim and Loayza 2019, and also chapter 3 in this volume), respectively. The LTGM-HC combines average years of schooling by age cohort with the quality of education and health components to determine human capital. In the LTGM-TFP, the TFP growth rate is calculated as the composite effect of TFP determinants: innovation, education, market efficiency, infrastructure, and institutions. The models are described in more detail in appendix 1 and most are available for download at www.worldbank.org/LTGM.

Our first result concerns a Malaysia's business-as-usual baseline growth path, where the growth drivers–public and private investment-to-GDP ratios, total factor productivity (TFP), human capital, and labor force participation rates–follow their historical or recent trends (future demographic projections taken from the United Nations (UN). We find trend GDP growth in Malaysia is likely to fall from around 4.5 percent in 2020 to 2.0 percent in 2050, driven mostly by demographics, falling private investment effectiveness, and declining TFP growth. Declining growth is common among peer countries as they transition to high-income status.

However, this decline in growth is not destiny, and our second finding is that it can be partially offset by economic reforms. Specifically, we simulate weak, moderate, and strong reforms for each growth driver, with targets set with reference to the distribution of those values among high-income (HI) countries. While weak reforms have little effect (relative to the baseline), moderate and strong reforms generate growth in 2050 that is 1.5 to 1.8 times that in the business-as-usual baseline (respectively).

The rest of the chapter is organized as follows. Section 1 presents the historical developments for each growth driver. Section 2 discusses the assumptions regarding growth drivers and parameters used in the baseline simulation. Section 3 shows the baseline GDP growth trajectory over the next three decades and analyzes the contribution of each growth driver to both current growth rates and changes in the growth rate over 2020–2050. Section 4 presents the impact on GDP growth of the different levels of reforms for each determinant of growth: "weak" reform benchmarking at the 25th percentile among high-income countries; "moderate" reform, at the 50th percentile; and "strong" reform, at the 75th percentile. Section 5 discusses the implications for GDP growth when the effects of all growth drivers are combined for each scenario of weak, moderate, and strong reform. Section 6, the conclusion, provides a summary of main findings and policy implications.

1. Historical developments in growth drivers

In this section we review the historical drivers of growth in Malaysia through the lens of the LTGM. First, we describe historical trends in GDP growth and GDP per capita growth, which provide context for future growth performance. Then we discuss the historical path of the investment-to-GDP ratios (both public and private), TFP growth, human capital growth, demographics, and the labor force participation rate, which help us calibrate the future paths of these growth drivers.

Post-2000, GDP growth in Malaysia has averaged 5% (figure 5.1), but growth has slowed relative to the faster rate in the 1990s. Slower growth rates as countries develop are however common, as we discuss in more detail in section 3. Malaysia has also experienced a relatively steady rate of per capita GDP growth of 3.3% over the past 20 years. These growth rates have allowed the real GNP per capita level to double since the mid-1990s. However, otherwise steady growth has been marked by slowdowns resulting from the Asian Financial Crisis in 1997, the 2009 Global Financial Crisis, earlier recessions around 1985 and 1975, and the recent 2020 COVID-19 pandemic (based on forecasts).

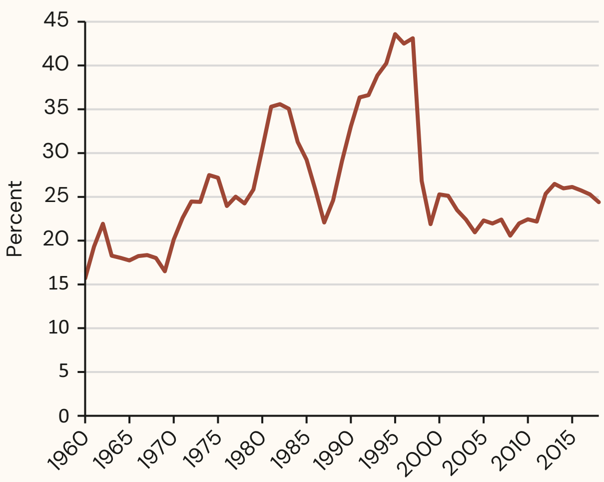
High-income status is defined by the World Bank as countries with gross national income (GNI) per capita above US$12,376 in 2019–2020 (measured at Atlas exchange rates). In 2018, Malaysia's GNI per capita was at $10,460 (figure 5.2) and historical trends suggest that Malaysia is expected to pass the threshold in the mid-2020s. However, this projection might be delayed due to the effect of COVID-19, causing a reduction in the forecasted growth in 2020 and possibly in the early 2020s (figure 5.1).[5]

Aggregate investment-to-GDP has averaged 24% over the last two decades (figure 5.3), with public investment trending down and private investment trending up (figure 5.4). During the late 1980s and 1990s, investment rates in Malaysia increased rapidly, reaching over 40% of GDP just before the 1997 Asian financial crisis. High private investment-to-GDP rates were buoyed by the First Industrial Master Plan (1986–1995), and liberalization and deregulation in the economy. In the 1990s, excessive investments also occurred in certain sectors, especially the property sector. After the Asian financial crisis, the investment-to-GDP ratio declined, with the fall mostly due to lower levels of private investment (not shown). In the last 10 years, investment-to-GDP has averaged 24.6%. A closer look at the split between public and private investment shows that public investment has been declining since 2012, falling from around 11% to 7% of GDP in 2018. This is reflective of the government's fiscal consolidation plan. At the same time, some rebalancing has been observed with private investment rising from 15% to 17% of GDP.

The median TFP growth over the past 30 years (1985–2014) is 0.9% (figure 5.5). Since TFP is calculated as a residual—growth less factor accumulation—it is volatile and oscillates with the economic cycle.

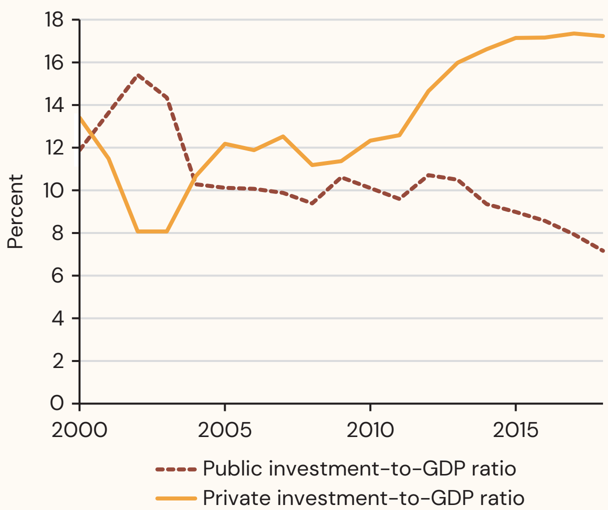
The human capital growth rate has experienced a downward trend since the early 1990s and it has averaged roughly 0.6–0.7% in the 2010–2014 period (figure 5.6). Human capital is a commonly measured using the average years of schooling, though in our forward-looking simulations we use a broader measure based on the World Bank Human Capital Index that includes schooling quality and population health. In the 1980s and early 1990s, human capital grew at around 2.0% but now has slowed to 0.6%. As it is harder to increase the average years of education when people are already well educated, countries often experience a slowing growth rate of human capital over time. We expect this trend will continue for Malaysia as it moves to high-income status.

Figure 5.3: Historical Investment-to-GDP (%)



Source: WDI. Code: NE.GDI.FTOT.ZS.

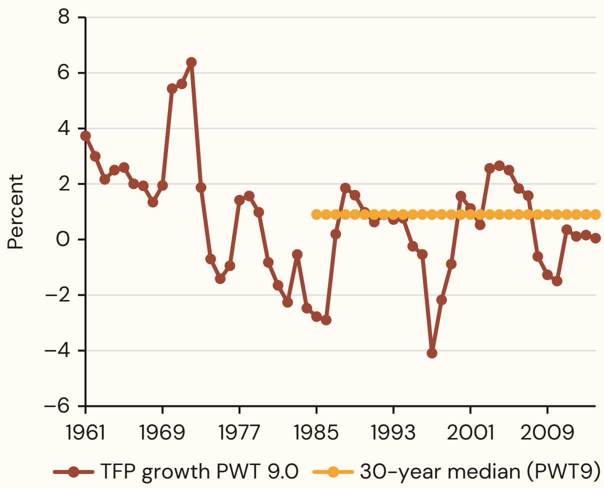
Figure 5.4: Historical Public and Private Investment-to-GDP (%)



Source: WDI. Codes: NE.GDI.FTOT.ZS, NE.GDI.FPRV.ZS.

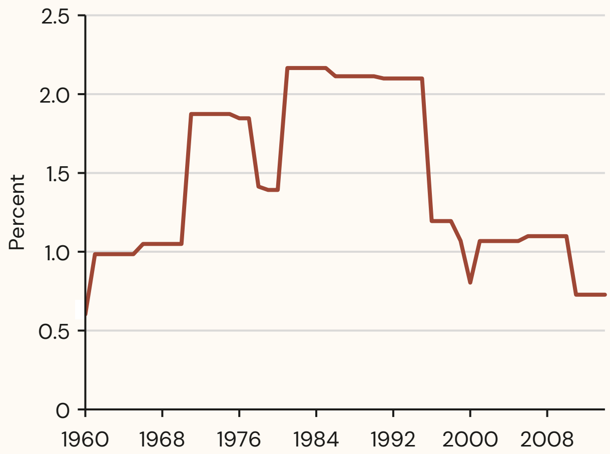
[5] World Bank (2020) projects a growth rate of –0.1% under the baseline and –4.6% under a low-case scenario for 2020.

Figure 5.5: Historical TFP Growth



Source: PWT 9.0.

Figure 5.6: Historical Human Capital Growth



Source: PWT 9.0.

Total population growth was close to 1.3% over the past five years, after experiencing a downward trend since 1990 (figure 5.7). Before 1990, population growth averaged 2.5–3.0%. Slower population growth is typical of developing economies that transition into high-income economies and is expected to continue. Slowing population growth also affects the share of population of working age (15–64), which in turn affects the size of the labor force (figure 5.8). The share of the population between ages 0 to 14 has been declining, due to falling fertility, which has led to a "demographic dividend": the share of the population of working age grew by around 0.6% over 1965–2010, and then accelerated to 1.0% in the 2000s (figure 5.9). Analytically, the LTGM suggests this demographic dividend contributed at least 0.3ppts to GDP growth throughout this period.[6] Since 2010, we can observe a declining growth rate of the share of the population of working age (figure 5.9), which has recently approached zero. This is the result of an aging population—fewer children and longer life expectancy—and is a characteristic of an economy transitioning to high income status. Examples of population aging can be found in developed economies like Japan, the Republic of Korea and Western Europe, and is expected to continue.

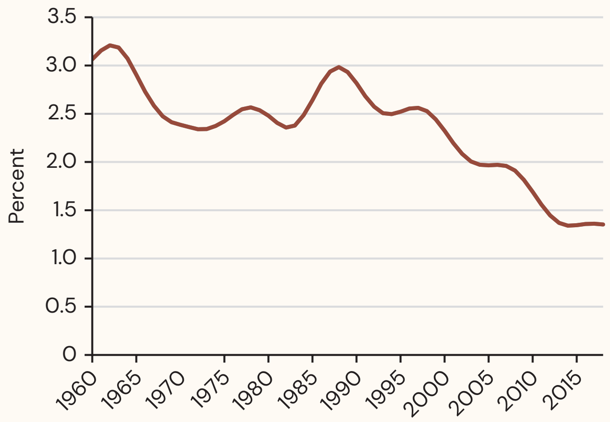
Historically, the labor force participation rate has been stable at around 64%, until 2010 when it increased to 68% by 2018 (figure 5.10). This is mostly due to higher female labor force participation (FLFP), which increased from about 46% in the 1990–2010 period to 55% by 2018. In contrast, male labor force participation has remained relatively constant at around 80% since 1990. Despite the increase in recent years, Malaysia's FLFP is still lagging its regional peers, such as Thailand, China, and Singapore and as well as high-income peers (figure 5.11). Higher rates of FLFP increase the labor supply in the economy, and hence the level of GDP per capita.

2. Growth drivers in the business-as-usual baseline

In this section we explore the assumptions that are required to calibrate the LTGM-PC to simulate Malaysia's business-as-usual baseline over 2020–2050. To create a business-as-usual baseline for the Malaysian economy in the long run, we need to calibrate the future paths of the growth drivers like investment, and the growth of both TFP and human capital, as well as other key parameters. These assumptions are summarized

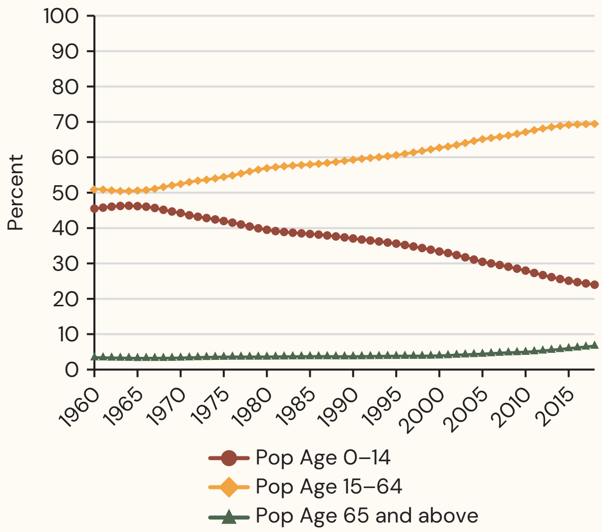
[6] Analytically, the 0.6ppts of growth in the working age to total population ratio will be multiplied by the labor share of income, which is 50%, resulting in about 0.3ppts to GDP growth each year.

Figure 5.7: Historical Total Population Growth (%)



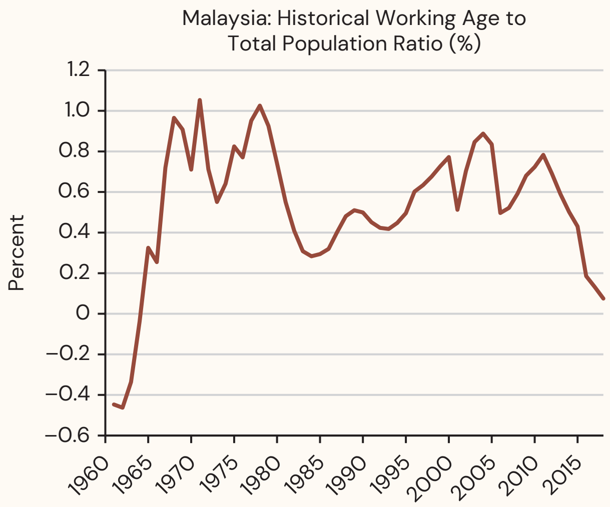
Source: WDI & UN Population Projections. Code: SP.POP.TOTL.

Figure 5.8: Historical Population Age Cohort Shares (%)



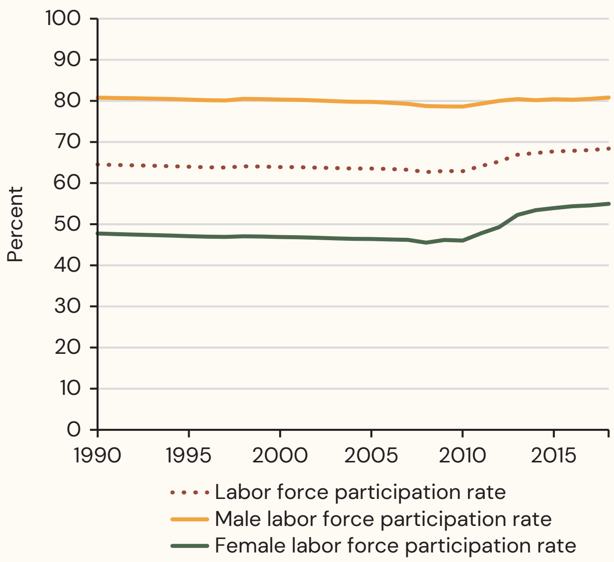
Source: WDI. Codes: SP.POP.0014.TO.ZS, SP.POP.1564.TO.ZS, SP.POP.65UP.TO.ZS.

Figure 5.9: Historical Growth in the Working Age-to-Population Share (%)



Source: WDI. Code: SP.POP.1564.TO.

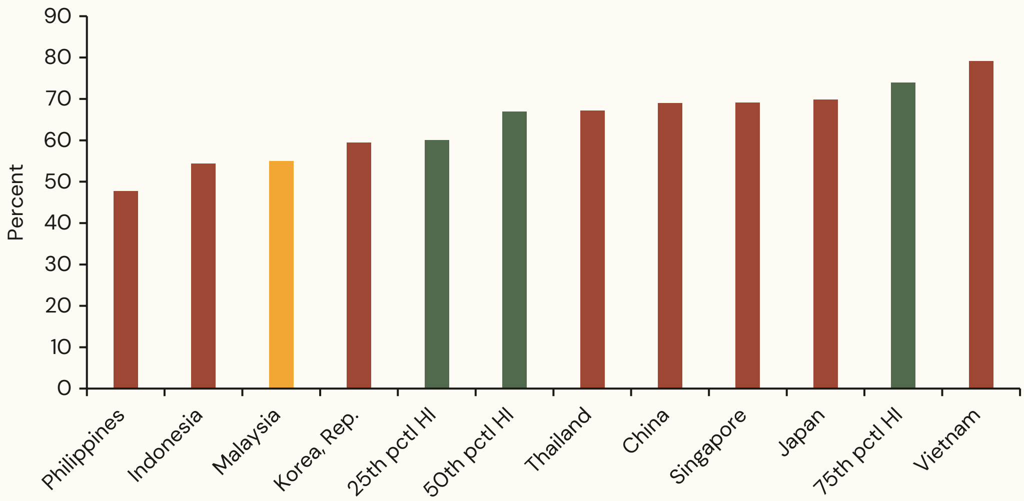
Figure 5.10: Historical Labor Force Participation (%)



Source: WDI. Code: SL.TLF.ACTI.MA.ZS, SL.TLF.ACTI.FE.ZS, SL.TLF.ACTI.ZS.

in table 5.1. We calibrate the LTGM-PC as the foundation of the analysis and add the LTGM-TFP extension and the LTGM-HC extension to simulate TFP growth and human capital growth, respectively. Additionally, short-to-medium term forecasts produced by the International Monetary Fund (IMF) in its Article IV report help us calibrate the future paths of public and private investment. We use population growth projections (by age cohort) from the UN for demographic trends until 2050. The remaining projections are determined by assuming that long-term trends in Malaysia remain constant and by performing some

Figure 5.11: Comparative Female Labor Force Participation in East Asia (%)



Source: WDI using data for 2018. Code: SL.TLF.ACTI.FE.ZS.

Table 5.1: Summary of Assumptions for the Malaysia Business-as-Usual Baseline

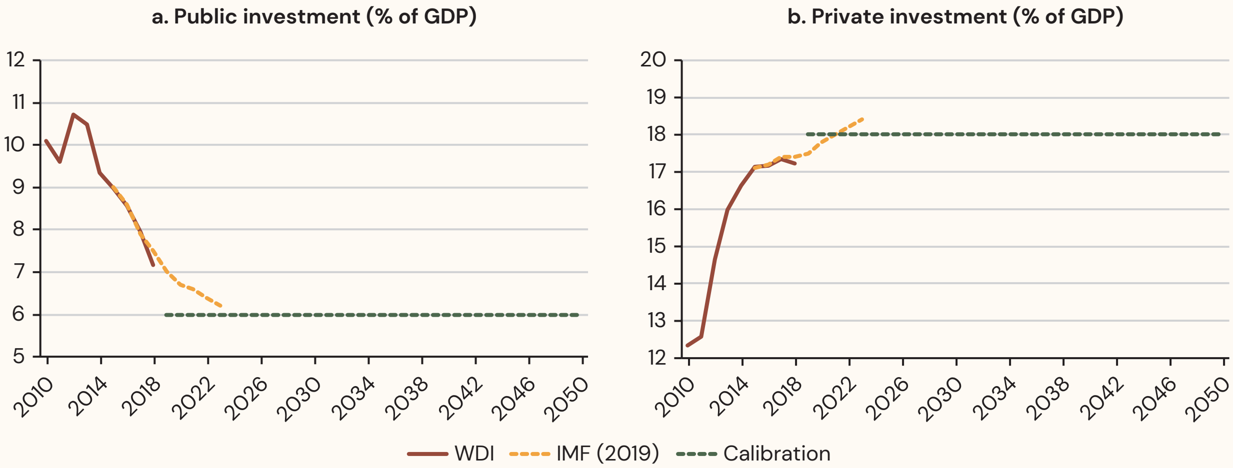
Variable	Baseline	Source/comments
Labor share	50.0%	Similar to the 2014 PWT 9 figure of 53%
Depreciation rate (aggregate)	5.8%	PWT 9 figure for 2014
Capital-to-output ratio	2.25	At steady-state value
Human capital growth	0.6% – 0.1%	Calculated using the LTGM Human Capital Extension
TFP growth	0.9% – 0.6%	Similar to the last 15-year average and the last 30-year median using PWT 9
Investment-to-GDP ratio	24%	Based on projections of public and private-investment-to-GDP
Public investment-to-GDP ratio	6.0%	Based on recent trend and IMF projection up to 2023
Private investment-to-GDP ratio	18.0%	Based on recent trend and IMF projection up to 2023
Population growth	1.3% – 0.4%	UN population projections (via WB HDN)
GDP Growth 2020–2050	4.5% – 2.0%	4.6% is MTI forecast for 2020 and 4.8% is the IMF Oct. 2019 WEO projections average for 2020–2023.
Atlas GNI PC level	US$10,460	World Bank WDI for 2018

steady state calculations. The labor share of income is calibrated to 50%, which is close to its value from Penn World Tables version 9.0 (PWT 9).

Investment-to-GDP is assumed to remain around 24%, given recent trends and the IMF Article IV projections for the next few years. For the baseline, we calibrate public investment-to-output and private investment-to-output ratios (I^G/Y and I^P/Y) of 6 percent and 18 percent, respectively (figure 5.12). This is based on projections made by IMF (2019), which forecasts that I^G/Y declines from 7.0 percent in 2019 to 6.2 percent by 2023, and I^P/Y increases from 17.5 percent to 18.4 percent over the same five-year period.[7] The calibrations

[7] These baseline projections by the IMF assume GDP growth of 4.8 percent, debt-to-GDP remaining around 50.0 percent, a fiscal deficit around 3.0 percent, and roughly stable revenue mobilization rates over the next five years.

Figure 5.12: Baseline Investment-to-Output Ratios



are consistent with (i) the gradual downward trend in I^G/Y in recent years amid fiscal consolidation, and (ii) a rebalancing toward private investment.[8]

The baseline projections put Malaysia between the 75th and 90th percentiles of the distribution of I^G/Y among high-income countries and at the 50th percentile for I^P/Y (table 5.2). Generally, I^G/Y declines and I^P/Y increases as countries move from lower to higher country income group classifications. One reason underlying the comparatively high I^G/Y in Malaysia is that public investment includes investment spending by state-owned enterprises (SOEs).[9] While the classification of expenditure by SOEs as public investment may differ country-to-country, there are some indications that public investment tends to be higher in countries that have a significant presence of SOEs.[10]

The efficiency of public investment, as reflected by the Infrastructure Efficiency Index (IEI) in the LTGM-PC, is high in Malaysia. Malaysia's IEI score of 0.877 puts it at about the 50th percentile among high-income countries. This indicates that infrastructure in Malaysia is well constructed and of high quality, which is supported by the World Economic Forum's survey on infrastructure quality for its Global Competitiveness Index—Malaysia ranked 21st of 137 countries in 2017–2018. Given the high base, the potential growth

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8 Our projections, indicative of longer-term trends, are also consistent with the near-term projections of the government for I^G/Y, but higher in the case of I^P/Y. Ministry of Finance Malaysia (2019) estimates I^G/Y and I^P/Y at 6.5 percent and 16.8 percent respectively for 2019 and forecasts these ratios at 6.1 percent and 16.3 percent respectively for 2020.

9 Known as non-financial public corporations (NFPCs) in Malaysia, these enterprises are public sector agencies undertaking the sale of industrial and commercial goods and services. They include government-owned and/or government-controlled companies. The government's monitoring and reporting are focused on major NFPCs, which have government ownership of more than 50 percent of total equity, minimum annual sales of at least MYR100 million and/or significant impact to the economy (Ministry of Finance Malaysia 2018).

10 In a list of 21 countries with the highest shares of SOEs among their top 10 firms and which also have at least 10 firms on the Forbes Global 2000 list (Kowalski et al. 2013), Malaysia is ranked fifth. Among the top 10 countries on this list (China, United Arab Emirates, the Russian Federation, India, Malaysia, Saudi Arabia, Indonesia, Brazil, Norway, and Thailand), we calculate the median value for average I^G/Y over 2006–2015 as 7 percent. Our calculations also indicate that the baseline projection of 6 percent for Malaysia's I^G/Y is slightly below the 75th percentile value for average I^G/Y over 2006–2015 (6.8 percent) of high-income fuel-based economies (fuel exports/merchandise exports >15 percent).

Table 5.2: Investment-to-Output Ratios by Country Income Groups, Average over 2006–2015 (percent)

Income group	P10	P25	P50	P75	P90
Public investment-to-output, I^G/Y					
High	2.3	3.1	4.0	4.8	6.8
Upper middle	3.2	4.2	5.4	6.7	10.8
Lower middle	2.7	3.6	5.6	7.7	11.5
Low	4.7	5.8	7.0	8.6	11.5
Private investment-to-output, I^P/Y					
High	13.7	15.9	18.2	19.8	22.3
Upper middle	12.9	16.0	17.7	21.0	23.7
Lower middle	7.8	13.8	16.3	21.5	25.2
Low	7.6	11.2	12.8	18.4	22.6
Investment-to-output, I/Y					
High	18.9	20.3	22.5	23.8	27.3
Upper middle	19.4	21.3	24.2	27.3	32.6
Lower middle	15.9	17.9	23.0	28.2	31.1
Low	13.5	18.4	22.3	24.6	33.0

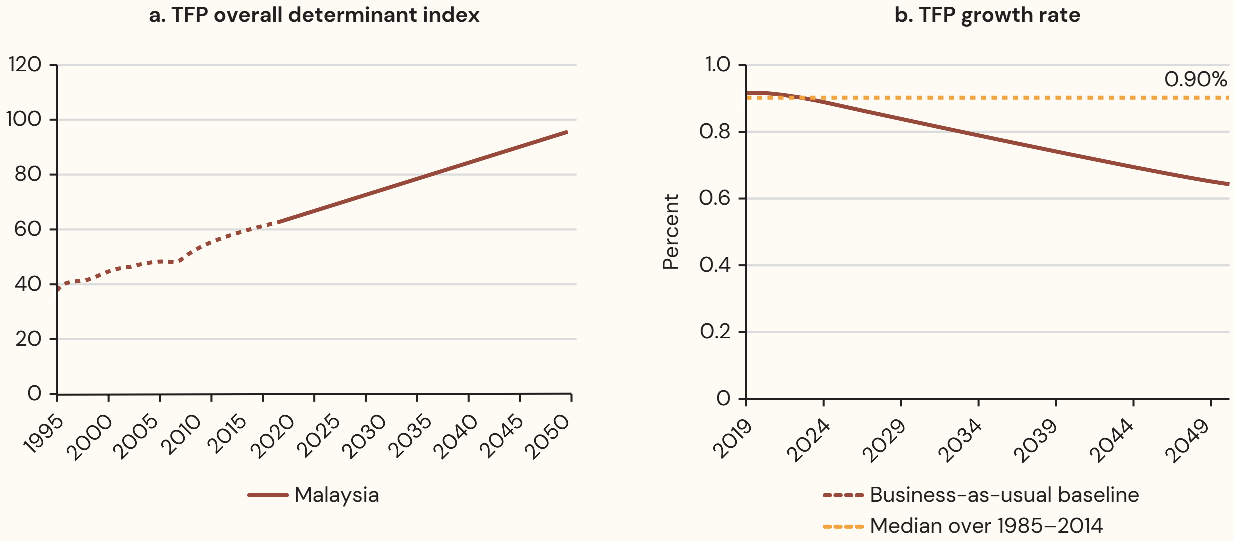
Notes:
- Data reported are 10-year average (2006–2015) investment to GDP shares at various percentiles (from 10 to 90) of each income group distribution.
- The sample comprises 144 countries: 43 high-income, 38 upper-middle-income, 34 lower-middle-income, and 29 low-income. Countries are categorized into income groups based on World Bank classification.
- I/Y data are obtained from WDI. I^G/Y and I^P/Y are calculated by splitting the WDI data on I/Y using public and private investment shares of total investment from the IMF Fiscal Affairs Department Investment and Capital Stock Database (which has data available up to 2015).
- Our baseline projections for Malaysia places it between the 75th and 90th percentiles of the high-income country distribution for I^G/Y, and at the 50th percentile for I^P/Y

impact from improvements in this measure of efficiency is limited, and so we assume quality is constant at its current rate in the baseline and all scenarios.

The IEI is best thought of as capturing public capital construction quality, which does not capture other less quantifiable, but important, aspects of public capital quality like poor project selection or an inflated cost of construction. We are, thus, unable to properly examine the implications of improvements on these elements in the model, especially in the context of cross-country comparisons. However, it does not mean that these elements are not important for Malaysia. For instance, IMF (2019) notes that fiscal vulnerabilities include reliance on off-budget spending and weaknesses in project appraisal, approval, and costing (Malaysia scores lower than the Organisation for Economic Co-operation and Development (OECD) average in terms of its procurement systems).

Total factor productivity (TFP) growth is assumed to be at the historical growth rate of 0.9%, the median over the period 1985–2014 in 2019, and then decline to 0.6% for the period of 2020–2050. This baseline TFP growth rate was generated using the LTGM-TFP extension (Kim and Loayza 2019) which assesses a country's potential for improving TFP growth depending on its determinants—innovation, education, market efficiency, infrastructure, and institutions. For the business-as-usual baseline, we assumed the TFP overall determinant index, the composite index of the subcomponent indexes for the five categories of the determinants, keeps increasing with the historical trend of the last 10 years. Specifically, we applied the average annual change in the overall determinant index over 2009–2018 to the period of 2019–2050 as shown in figure 5.13a. With this assumption, we simulated TFP growth using the LTGM-TFP extension. Figure 5.13b shows that the TFP growth rate is expected to decrease gradually from around 0.90% to 0.64% over the next three decades.

Figure 5.13: Business-as-Usual Baseline for the TFP Overall Determinant Index and the TFP Growth Rate



We assume that future human capital growth begins at 0.6% in 2020 and declines to about 0.1% in 2050 (figure 5.14). The human capital growth path for the baseline is produced using the LTGM-HC extension. We assume the average expected years of schooling in the future is the same as that of today's children, 12.2 years. Because today's new workers are better educated than older workers moving to retirement, the average human capital of the workforce increases over time—despite no increase in schooling of children—leading to a positive human capital growth rate. The declining rate of human capital growth is because the average education quantity increases over time, and so the boost to the average from higher-skilled young workers is smaller. Human capital also includes the quality of education, as well as health. The health of the population is measured by adult survival rates (ASRs), which is the probability that a 15-year old will reach their 60th birthday, and stunting rates, defined as the fraction of 5-year-olds that are not stunted (see equation below).

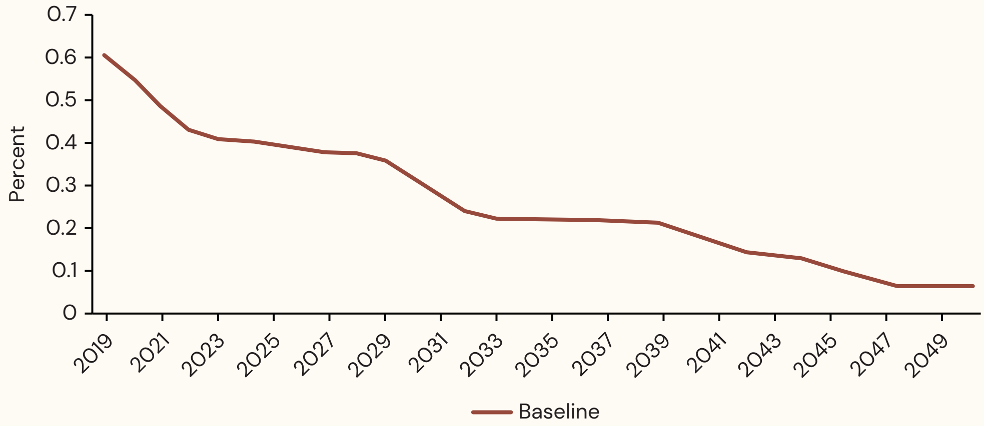
$$h_t^{HCI} = Schooling_t \times Health_t$$
$$= e^{\phi(YrsSchool_t \times Quality_t - 14)} \times e^{\frac{[\gamma_{Stunt}(NotStunted_t - 1) + \gamma_{ASR}(ASR_t - 1)]}{2}}$$

In the baseline, we assume that schooling quality remains at its original level of 0.75, ASRs stay at 0.88, and the not stunted rate stays at 0.79. Data on the health and education variables are taken from the World Bank's Human Capital Project.[11] Due to a lack of historical data, we also assume that those rates apply to the whole working-age population, and so schooling quality and health make no contribution to human capital growth in the baseline. In terms of growth rates, human capital grows at about 0.6% in 2019–2020, and it slowly declines to under 0.1% by 2050. The return to education is assumed to be 12%.

The capital-to-output ratio is assumed to be at its steady-state value of around 2.3. The steady-state capital-to-output ratio is calculated as the ratio of the investment share of GDP to the sum of trend GDP

[11] See https://www.worldbank.org/humancapital.

Figure 5.14: **Baseline Simulation of Human Capital Growth**



growth and depreciation rate (see equation below).[12] We divide total capital into public and private shares from the IMF Fiscal Affairs Department Investment and Capital Stock Database 2017, resulting in 1.14 for the public capital-to-output ratio (Kg/Y) and 1.11 for the private capital-to-output ratio (Kp/Y), respectively.

$$\frac{K}{Y} = \left(\frac{I}{Y}\right) / (g_y + \delta) = \frac{0.242}{0.046 + 0.058} \approx 2.28$$

3. Business-as-usual baseline growth in Malaysia over 2020–2050

Under a baseline or business-as-usual growth path, Malaysia's trend GDP growth would slow from 4.5 percent today to 2.0 percent by 2050 (figure 5.15). The business-as-usual baseline in the LTGM measures the potential growth rate of the economy and is not a forecast of actual growth. Naturally, actual growth in 2020 is expected to be much lower than potential growth, due to the COVID-19 pandemic (dotted lines in figure 5.15). But, hopefully, the pandemic will not have much effect on the long-run growth potential that is the focus of this chapter. This section explains the drivers of current growth, the reasons for the declining trend, and, also, a comparison with some peer countries. Using this baseline simulation, Malaysia will achieve high-income status by 2024, but this is likely to change due to the prospective economic downturn caused by COVID-19 on the Malaysian economy.

A declining GDP growth rate, as projected in the baseline for Malaysia over 2020–50 is typical of economies transitioning to HI status. Figure 5.16 shows smoothed growth rates since 1960 for four economies that made the transition to high-income status (Hong Kong SAR, China; the Republic of Korea; Singapore; and Taiwan, China). All four economies experienced substantial slowdowns in growth rates. Therefore, it should not be surprising if Malaysia also has slowing growth over the next 30 years. Indeed, slower GDP growth rates are a characteristic of high-income economies.

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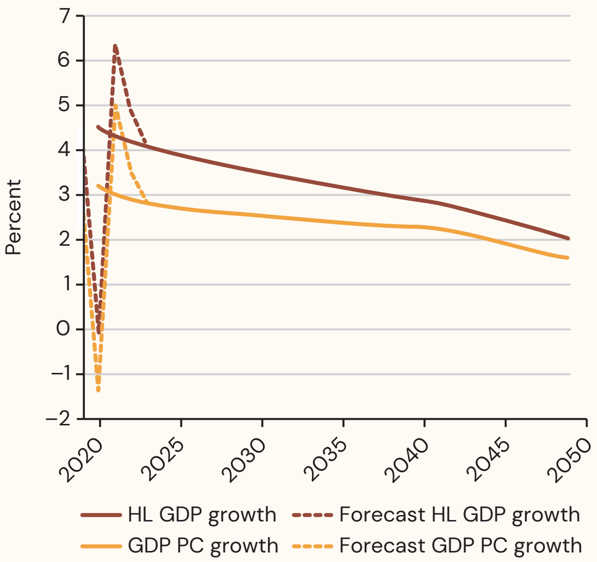
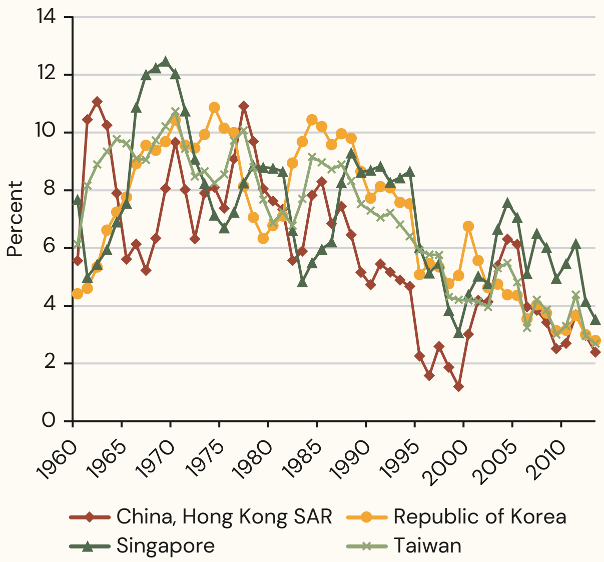
[12] The GDP growth rate used is the average of 4.6% in the past 10 years, and the depreciation rate 5.8% from PWT 9. An alternative approach is to calibrate the capital-to-output ratio using Penn World Tables data, which would have generated a total capital-to-output ratio of around 3, and a lower growth rate over the next few years. But that growth rate was inconsistent with other information, such as recent growth history and forecasts by policy institutions, so we chose the steady-state approach instead.

Figure 5.15: Malaysia's Business-as-Usual Baseline GDP and GDP PC Growth



Sources: LTGM Calculations & East Asia and Pacific Economic Update April 2020.

Figure 5.16: High-Income Asian Economics and GDP Growth Trends



What explains current trend growth rates?

Private investment, followed by productivity growth, are the largest drivers of current economic growth. Current growth rates can be decomposed using a log-linear approximation of the production function as in Devadas and Pennings (2019) (equation 16). Private investment is the most important growth driver, with a net contribution of about 2ppts of the current 4.5 percent GDP growth (figure 5.17, panel a). Private investment makes such a large contribution because of the current low private capital-to-output ratio—driven by many years of low private investment following the Asian Financial Crisis—which increases the current marginal product of private capital (figure 5.17, panel b). Note, however, that both the marginal product and growth contributions change over time, which we discuss in detail below. After private investment, the next largest contribution is from TFP growth, with a contribution of 0.9ppts. Next, population growth and public investment each contribute around 0.65ppts, with human capital growth contributing 0.3ppts.[13]

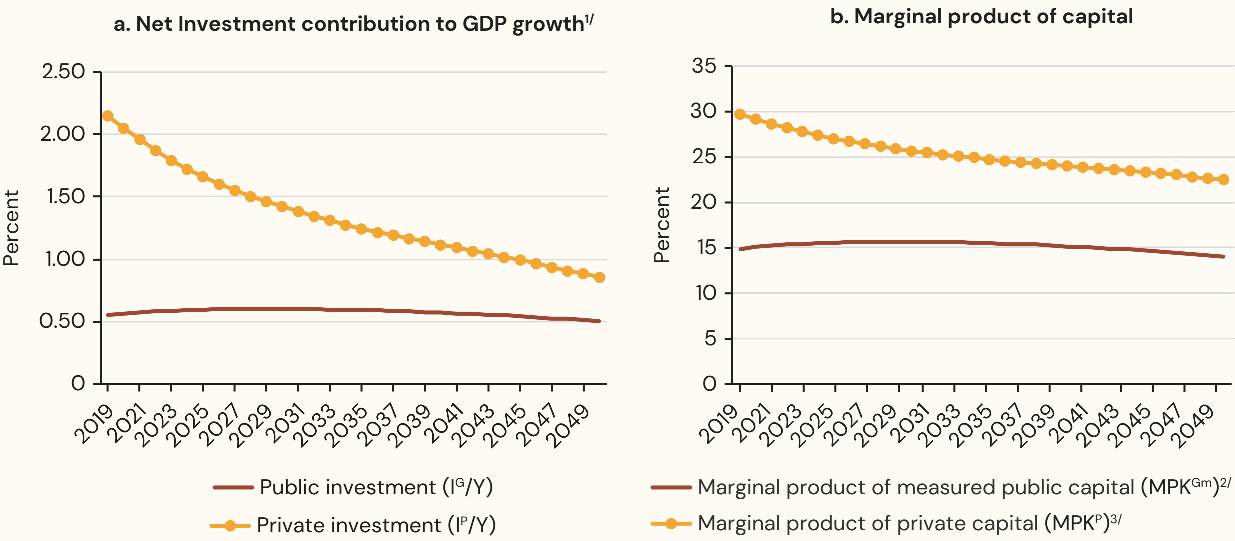
Why is the baseline growth rate declining?

A natural explanation for the declining baseline GDP growth rate might be declining population growth. While this falling population growth is part of the explanation, GDP per capita growth also falls from 3.2% to 1.5% over the same period (figure 5.15). The same set of peer countries in figure 5.16 also experienced declining GDP per capita growth (not shown).

To understand what is driving the fall in baseline growth, we run counterfactual simulations where the path of each growth driver (or its marginal product, for investment) is kept constant at current levels. Table 3.1 depicts the impact of each driver on the fall in GDP growth. These are normalized contributions, which means that the individual contributions, which are shown in appendix, figures 2.1–2.12, are scaled so that

[13] Changes in the working-age to total population ratio contribute approximately zero, as Malaysia is in the middle of a transition between a demographic dividend and an aging population (see figure 5.9). Labor force participation is assumed to be constant in the baseline, and so makes no contribution.

Figure 5.17: **Net Investment Contribution to GDP Growth and Marginal Product of Capital**



[1/] Net public investment contribution to GDP growth $\approx \phi\left(\frac{I_t^G/Y_t}{K_t^{Gm}/Y_t}-\delta^G\right)$.

Net private investment contribution to GDP growth $\approx (1-\beta-\phi)\left(\frac{I_t^P/Y_t}{K_t^P/Y_t}-\delta^P\right)$.

[2/] Marginal product of measured public capital, $MPK^{Gm}=\frac{\phi}{K_t^{Gm}/Y_t}$. is obtained by taking the derivative of equation (16) in appendix 1 with respect to I_t^G/Y_t. $\theta^N=\theta_t$, that is the efficiency of new investment remains the same as past investment

[3/] Marginal product of private capital, $MPK^P=\frac{1-\beta-\phi}{K_t^P/Y_t}$, is obtained by taking the derivative of equation (16) in appendix 1, with respect to I_t^P/Y_t.

Source: LTGM Calculations.

they add up to the total fall in growth over 2020–50. The normalization is necessary because over the long term, the model is substantially nonlinear.[14]

As foreshadowed above, population growth is expected to fall by 0.8ppts over 2020–2050 which has a normalized contribution of around 0.6ppts to the total baseline fall in GDP growth over the same period. Declining population growth reduces the growth of the labor force, which directly reduces GDP growth. This also reduces the marginal product of capital (which is proportional to the capital-to-output ratio), which reduces the effect of investment on growth.[15]

Declining population growth affects GDP growth and GDP per capita growth differently (in contrast, other growth drivers have the same effect on GDP per Capita and GDP growth).[16] Falling population growth actually raises per capita GDP growth: a 1ppt fall in population growth rate reduces the denominator ("per capita") by 1ppt but reduces GDP growth by less than 1 percentage point. In the baseline, GDPPC growth falls by 1.66% in the baseline, but only 1.88% with constant population growth (appendix, figures 2.1–2.2).

The falling working age-to-total population ratio (WATP ratio) reduces GDP and per capita GDP growth in the mid-2020s and also late 2040s (appendix, figures 2.3–2.4). The growth rate of the WATP ratio falls

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[14] Because the model is nonlinear, the sum of the effects of changing growth drivers at one-by-one is not equal to the total change in growth when the growth drivers change together. This is especially true over the long term when K_t^{Gm}/Y_t and K_t^P/Y_t change.

[15] This direct effect is about 0.4ppts of GDP growth, with the indirect effect via the effectiveness of investment being the rest.

[16] Note however, that the *normalized* contributions of the other growth drivers will be different for GDP and GDPPC growth.

Table 5.3: Understanding the Drivers of Malaysia's Falling Economic Growth Rates

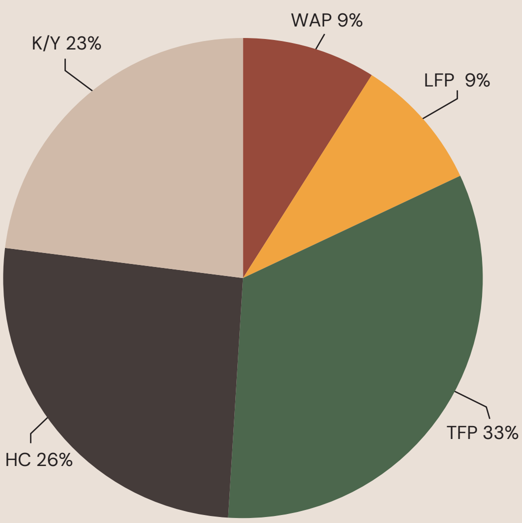
Baseline	Total fall GDP growth (2020–2050)	
	–2.5ppts Normalized contribution	100% Normalized share of fall in growth
Population growth	–0.63ppts	20%
WATP growth	–0.33ppts	11%
TFP growth	–0.40ppts	13%
HC growth	–0.39ppts	12%
Public investment (falling marginal product)	–0.04ppts	1%
Private investment (falling marginal product)	–1.37ppts	43%

Source: Authors' calculations.

Box 5.1: Republic of Korea's Economic Growth Experience

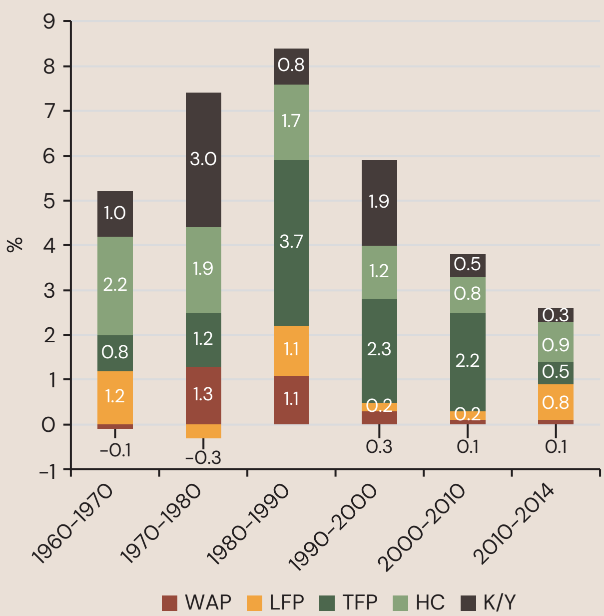
This box aims to summarize the Republic of Korea's economic growth experience as it transitioned to high-income status. Jeong (2017, 2018) (and the next chapter in this volume) argues that the historical growth drivers in Korea were diverse, but it was total factor productivity (TFP) growth and human capital growth that helped sustain its development (figure B5.1.1), and these were more important than physical capital accumulation. Real GDP per capita growth averaged almost 6% over 1960–2014,

Figure B5.1.1: Historical Drivers of Growth in Korea, 1960–2014



Source: Jeong 2017.

Figure B5.1.2: Historical Economic Growth in Korea, 1960–2014



Source: Jeong 2017.

(Box Continued on next page)

Box 5.1: (*Continued*)

with exceptionally fast growth in the 1970s and 1980s. Korea first gained high-income status in the mid-1990s and growth slowed after 2000, which is a characteristic of high-income economies.

Figure B51.1 shows the main economic growth drivers in Korea over time: (i) TFP growth (33%), (ii) human capital growth (26%), (iii) capital deepening (23%), (iv) growth in the working-age to total population ratio (9%), and (v) more involvement of both men and women in the labor force which boosted growth (9%).

Figure B5.1.2 is a historical account of Korean economic growth divided by decades from 1960 to 2014. Korea grew more due to human capital, labor force participation, and working age to total population growth in the 1960s. In the 1970s, physical capital accumulation was the most important driver of growth, followed by human capital growth. From the 1980s onwards—the period that corresponds to Malaysia's current development level—total factor productivity growth was the most important growth driver. TFP growth accounts for 3.7ppts of about 8% growth in the 1980s, 2.3ppts of 6% average GDP PC growth in the 1990s, and 2.2% of 4% in the 2000s.

by 0.6ppts by the end of the simulation period, resulting in a contribution of 0.33ppts to the overall fall in GDP growth over 2020–2050.

Falling TFP growth and Human Capital growth over 2020–2050 both account for around 0.4ppts of the fall in the GDP growth over 2020–2050. The median TFP growth rate over 1985–2014 is 0.9% (the value for the counterfactual), and the baseline TFP growth rate is expected to decrease from 0.9% to 0.6% over the next three decades (figure 5.13, panel b). Human capital growth falls from 0.6% (the value in the counterfactual) to 0.1% in the baseline, a 0.5ppts decline (figure 5.14). While this decline in human capital growth is larger than that of TFP, GDP growth rates are also less sensitive to human capital, resulting in similar contributions (appendix, figures 2.5–2.8).

Overall, the declining effectiveness of private investment makes the largest contribution to falling GDP growth in the baseline (1.4ppts, or 40% of the total). In contrast, changing public investment effectiveness makes little contribution. Investment rates (public and private) are constant in the baseline, but they can still contribute to declining growth through changing marginal products. The marginal product of private capital is currently very high, reflecting low rates of private investment after 2000 and solid historical growth rates. As private investment is now higher, and growth is slower, the marginal productivity of private investment is expected to fall through 2050 back to more normal levels.

In our model, the initial private capital-to-output ratio K^p/Y is relatively low at 1.14 (about the same as the public capital-to-output ratio K^{Gm}/Y of 1.11), thus allowing for a much higher marginal product of private capital. However, with high I^p/Y at a constant 18 percent, K^p/Y also increases faster than K^G/Y (which increases only slightly, due to a public investment share-to-GDP of 6%). As such, in the baseline the marginal product of private capital shows a larger decline, and the GDP growth effect of I^p/Y falls more noticeably over time.

4. Scenario analysis (analysis of shocks to each growth driver)

In this section, we study the impact on growth from shocks to investment, human capital growth, TFP growth, and FLFP. These are based on, or with reference to, 25th, 50th, and 75th percentiles among high-income countries ("aspirational goals"). Weak reform scenarios for some factors will be above the baseline.

Additionally, we include a short box on the impact of rebalancing between public and private investment (unchanged total investment), when discussing investment shocks to better understand their relative effects.

4.1 Public and Private Investment Scenarios

4.1.1 Shocks to Public Investment

We consider two alternative public investment scenarios: a 1ppt GDP increase in public investment (strong reform), and a 1ppt GDP fall in public investment (weak reform). The +1ppt shock, which could reflect strong revenue mobilization reforms amid faster fiscal consolidation than the baseline, brings I^G/Y to the 90th percentile of the high-income country distribution. The -1ppt shock could reflect faster fiscal consolidation than the baseline, but with poor revenue mobilization reforms, it would take public investment as a share of GDP to the 75th percentile.

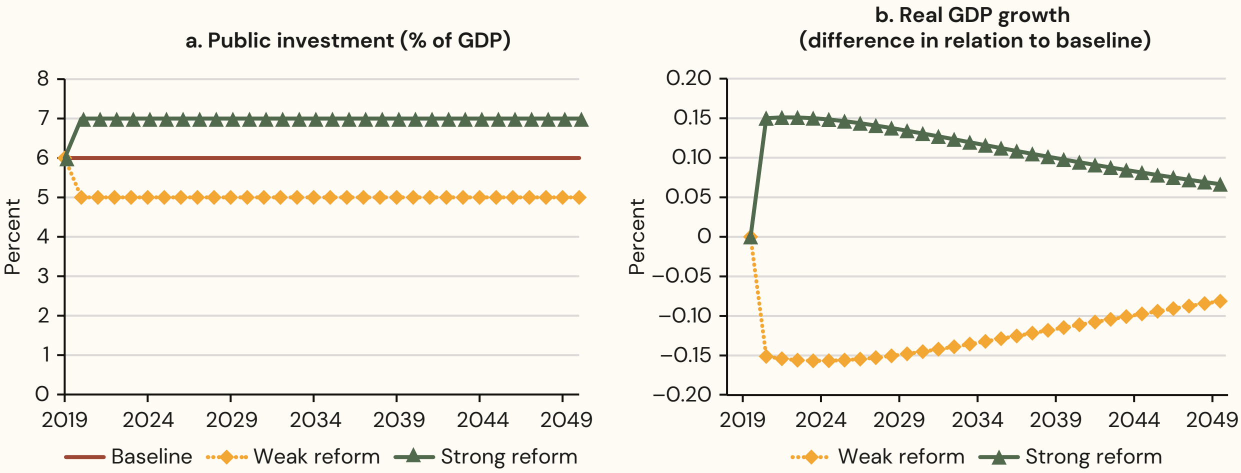
When we shock the public investment-to-GDP ratio by increasing it from 6% to 7%, GDP growth is boosted by approximately +0.15ppts over 2021–2030 and approximately +0.10 over 2031–2050. A roughly symmetric effect on growth, but in the opposite direction, occurs with a decrease in public-investment-to-GDP from 6% to 5%. Figure 5.18, panel a illustrates the shocks to I^G/Y comprising strong reform (+1ppt) and weak reform (–1ppt) scenarios; and panel b, the effects on GDP growth in relation to the baseline. I^P/Y is unchanged from the baseline in these simulations.

4.1.2 Shocks to Private Investment

We consider larger shocks than we did for I^G/Y, as I^P/Y is higher and varies more across high-income countries. The +2ppts shock, which we assume occurs as the government delivers reforms that strengthen the ecosystem for private investment and promotes a rebalancing of investment, brings I^P/Y to the 75th percentile of the high-income country distribution while the –2ppts shock, reflecting insufficient reforms amid fiscal consolidation, takes it to the 25th percentile and is also approximately Malaysia's average over 2010–2018.

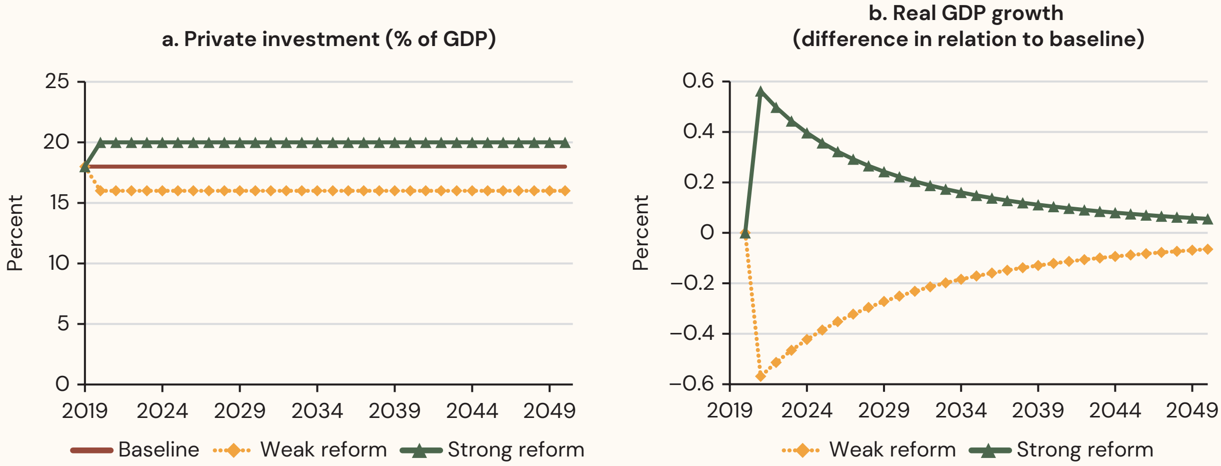
When we shock the private investment-to-GDP ratio by increasing it from 18% to 20%, GDP growth is boosted by approximately +0.36ppts over 2021–2030. But the growth effect falls off sharply—by about two-thirds to +0.11ppts over 2031–2050. A decrease in private investment-to-GDP from 18% to 16% reduces GDP growth by −0.39ppts over 2021–2030 and −0.13ppts over 2031–2050. Panel a of figure 5.19 illustrates the shocks associated with strong reform and weak reform respectively to I^P/Y, comprising +/− 2ppts, and graph B the effects on GDP growth in relation to the baseline. I^G/Y is unchanged from the baseline in these simulations.

Figure 5.18: Shocks to I^G/Y — Impact on GDP Growth



Source: LTGM Calculations.

Figure 5.19: Shocks to I^P/Y—Impact on GDP Growth



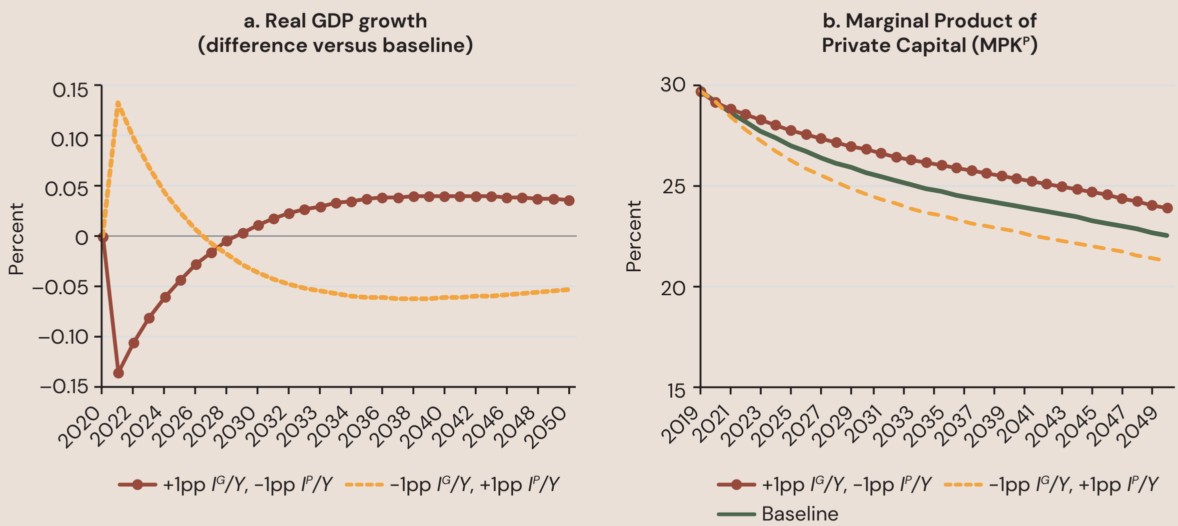
Source: LTGM Calculations.

Box 5.2: Rebalancing Components while Keeping I/Y Unchanged—A Comparison of the Effects of I^G/Y and I^P/Y on GDP Growth

We consider two scenarios, in which total I/Y remains unchanged from the baseline at 24 percent. In the first scenario, we increase I^G/Y by 1ppt to 7 percent and reduce I^P/Y to 17 percent from 2020. There is an initial decline in GDP growth in relation to the baseline (line with marker in panel a of figure B5.2.1) given the loss of private investment impact at a high MPK^P but the differential turns positive by 2029 and remains so thereafter because K^P/Y rises more slowly compared to the baseline and MPK^P is therefore higher (line with marker in panel b of figure B5.2.1).

In the second scenario, we reduce I^G/Y by 1ppt to 5 percent and increase I^P/Y to 19 percent from 2020. In contrast to the first scenario, there is an initial increase in GDP growth in relation to the baseline, but the differential turns negative by 2027 (dotted line in panel a of figure B5.2.1), as K^P/Y rises more quickly compared to the baseline and MPK^P declines faster (dotted line in graph B of Box Figure 3).

Figure B5.2.1: Rebalancing Investment Components—Impact on GDP Growth



4.2 Total Factor Productivity Growth

We model three TFP scenarios with different levels of reform by benchmarking Malaysia against high-income countries. The simulations include a weak reform scenario which targets a low value over a long period, a strong reform scenario which targets a high value over a short period, and a moderate reform scenario in the middle. We assume each subcomponent index for innovation, education, market efficiency, infrastructure, and institutions, which are identified as main determinants of TFP based on a literature review (Kim and Loayza 2019), increase linearly to the 25th, 50th, and 75th percentiles among high-income countries for the scenarios of weak, moderate, and strong reforms, respectively. The number of years to reach the target is 75th (long), 50th, and 25th (short) percentile, respectively, in the distribution of years that the high-income countries took from the Malaysia's current level (in 2018) to the target. For example, for the strong reform scenario for education, there are five high-income countries which achieved the target of 77.53 (75th percentile in the education index and Sweden's current level). There is variation in the number of years these countries took from the current Malaysia's level (52.07 in 2018) to the target. We then calculated the 25th percentile among the years the five countries took, 20 years, as the duration to reach the target for Malaysia. Table 5.4 lists Malaysia's values for each component of the TFP index, the different targets and number of years to target.

Only in the strong reform scenario are the growth rates of TFP, GDP, and GDP per capita expected to exceed those of the business-as-usual baseline. Figure 5.20 shows the path of the TFP determinant index under the scenarios of weak, moderate, and strong reforms, and figures 5.21–5.23 show the results of the simulations for the growth of TFP, total GDP, and GDP per capita (respectively). In the weak reform scenario, the

Table 5.4: Scenarios of Weak, Moderate, and Strong Reforms for the Projection of TFP Growth for 2020–2050

	Sub-components of the TFP index				
	Innovation	Education	Market efficiency	Infrastructure	Institutions
Malaysia in 2018					
	24.79	52.07	85.26	60.20	69.45
Scenario 1. Weak reform					
Target value	21.03	60.28	71.66	60.47	72.99
Country	—	Spain	—	Portugal	Slovakia
Years to target	—[a]	8	—[b]	1	16
Scenario 2. Moderate reform					
Target value	40.24	71.49	86.89	68.68	82.22
Country	France	Netherlands	Italy	Finland	France
Years to target	9	21	2	13	19 [c]
Scenario 3. Strong reform					
Target value	59.46	77.53	90.98	73.93	91.70
Country	Denmark	Sweden	Germany	Switzerland	Germany
Years to target	10	20	4	16 [d]	39 [e]

[a, b] The subcomponent indexes are assumed to increase over the next 3 decades with Malaysia's historical trend of the last 10 years (2009–2018).
[c, e] All high-income countries achieved Malaysia's current level before 1985, the initial year in our database. We used the path of Japan of which the institutions index is the closest (74.01) in 1985 to the current Malaysia's level (69.45). The institutions index of Japan is assumed to linearly increase in 2019 and onwards with the average annual change of the last 10 years (2009–2018).
[d] All high-income countries achieved Malaysia's current level before 1985, the initial year in our database. We use the path of Slovenia of which the infrastructure index is the closest (62.62) in 1985 to the current Malaysia's level (60.20).
Note 1. All indexes range from 1, the worst performance, to 100, the best.
Note 2. See appendix 1: LTGM-TFP or Kim and Loayza (2019) for more details on the construction of the determinant indexes.

Figures 5.20-5.23: Simulated paths of the TFP overall determinant index and growth rates of TFP, GDP, and GDP per capita under the scenarios of weak, moderate, and strong reforms

Figure 5.20: TFP Overall Determinant Index

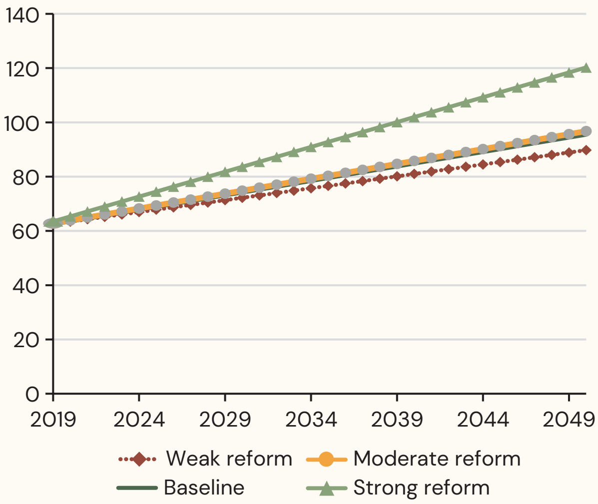


Figure 5.21: TFP Growth

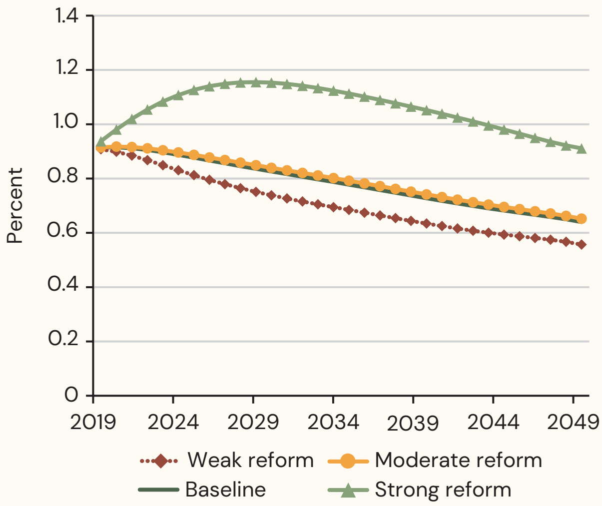


Figure 5.22: GDP PC Growth

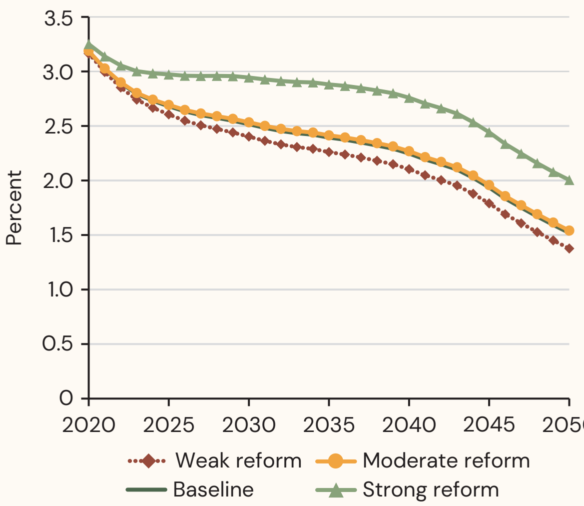
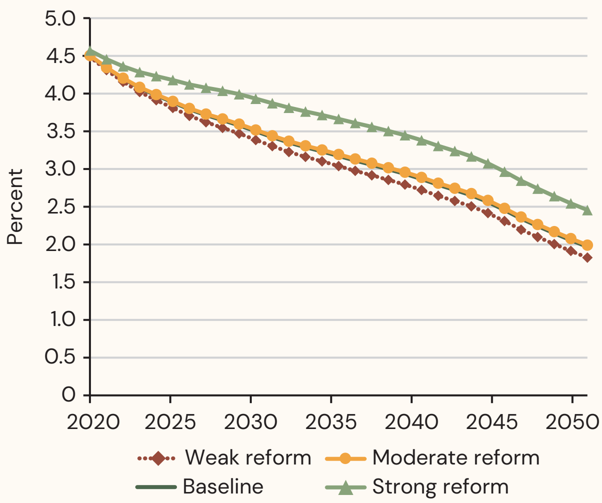


Figure 5.23: GDP Growth



Source: Authors' calculations.

growth rates are lower than those of the business-as-usual baseline. The moderate reform scenario leads to growth rates very similar to the baseline. Only with the strong reform scenario are the growth rates of TFP, total GDP, and GDP per capita are expected to be higher than those of the baseline.

The key message of the simulations is that the improvement of the TFP overall determinant index needs to be large and fast enough to maintain or accelerate TFP growth. In our econometric model for the LTGM-TFP extension, the change in TFP growth rate depends on changes in TFP determinant subcomponent indexes of innovation, education, market efficiency, infrastructure, and institutions, as well as the initial level of TFP. A larger projected change in TFP growth rate occurs with larger proportional increases in the TFP determinant subcomponent indexes and lower initial levels of TFP (see Kim and Loayza 2019).

In Malaysia's case, the current TFP overall determinant index is higher than in other developing countries on average; increasing it further is harder than in other countries with lower levels of the overall index. Also, Malaysia's current level of TFP is moderately high as compared to other developing countries. For these reasons, achieving higher TFP growth in Malaysia is more difficult than in the past in comparison to many other developing countries. Only with the scenario of strong reform are the growth rates of TFP, GDP, and GDP per capita expected to be higher than those of the business-as-usual baseline.

4.3 Human Capital Growth

This subsection models shocks to the quantity of education, quality of education, and health components (adult survival rates and children under 5 years of age who are not stunted) to the 25th, 50th, and 75th percentiles of high-income economies. The distribution of those four components are explored in figures 5.24–5.27, and it can be observed that Malaysia is behind other high-income economies in all four areas. We perform two sets of simulations: first by shocking all the components together to the different high-income percentiles, and second by shocking each HC component to the high-income country median one-at-a-time – to investigate the quantitative importance of each component.

By shocking the components of quality and quantity of education and health components of human capital to the 25th, 50th and 75th percentiles of high-income economies, GDP growth is boosted by roughly 0.10ppts, 0.30ppts, and 0.40ppts, respectively, on average during the 2020–2050 period (figures 5.28–5.29). The dynamics are also important. This immediate policy change causes no change in the growth rates of human capital or GDP until the mid-late 2020s, which is when the oldest children who were affected by the policy change start to join the labor force. Even then, the effects are small, as the oldest cohort of children spent the majority of their education under the old regime, and so only enjoy a fraction of the benefits. It takes until almost 2040 for the reforms to have their full effect: when today's toddlers—who received the full benefit of the reforms—start to join the labor market.

To understand the effect of each human capital component, we shock each component to the 50th percentile of the HI distribution one-by-one (figure 5.30). On average over 2020–50, a higher quality of education boosts GDP growth by 0.14ppts, an increase in the years of schooling boosts growth by 0.10ppts, increasing the adult survival rate boosts growth by 0.02ppts, and lowering stunting rates among children under five boosts growth by 0.02ppts (figure 5.31). Quantity and quality of education provide the biggest boost to economic growth in the long run.[17] In numerical terms, the high-income-median targets are 13.4 expected years of schooling, 83% quality of education, adult survival rate of 93% and the fraction of children not stunted under five of 93%. These improvements in human capital growth components prevent the decline in human capital growth in the baseline and instead boost it from 0.6% to 0.7% by 2050 (instead of falling to 0.1%).[18]

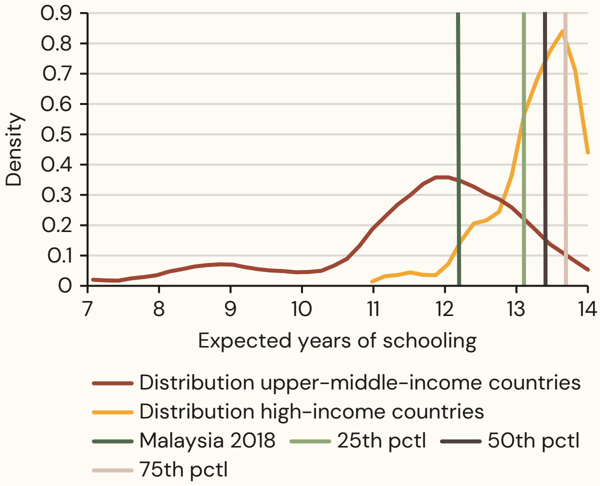
4.4 Female Labor Force Participation

An increase in female labor force participation (FLFP) to the 25th, 50th, and 75th percentiles of high-income economies boost average GDP growth over 2020–2050 by 0.14ppts, 0.31ppts, and 0.36ppts, respectively, relative to the business-as-usual baseline with unchanged FLFP. The FLFP rate in Malaysia is 55% as

[17] However, it should be noted that the health components improve the standards of living of Malaysians as a whole, and by being healthy, they are able to learn and improve their educational attainment and also be healthier workers. The LTGM-HC does not include the indirect effect of health on growth via high education.

[18] This simulation is similar to that in the June 2019 Malaysian Macroeconomic Monitor, the differences being that: (i) baseline has changed slightly to include a downward trend in TFP growth and (ii) quantity of education is also shocked.

Figure 5.24: Expected Years of Schooling



Source: HCI

Figure 5.25: Malaysia's Quality of Education

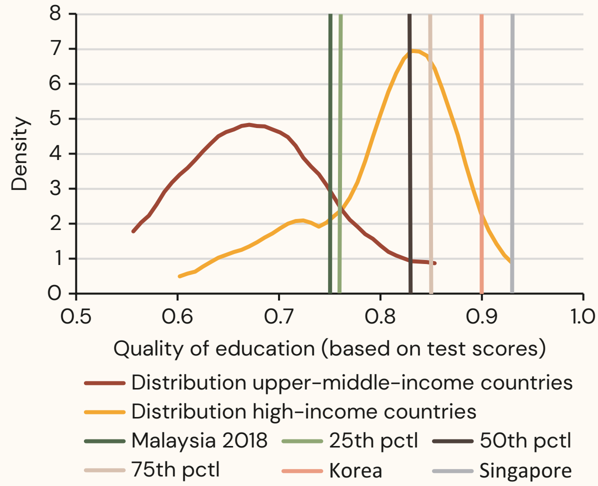


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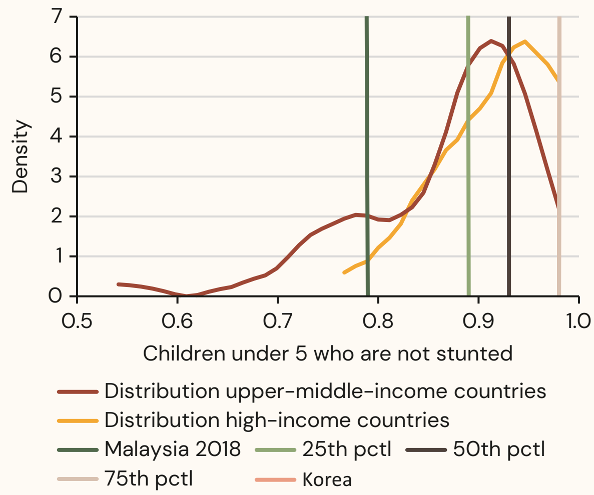
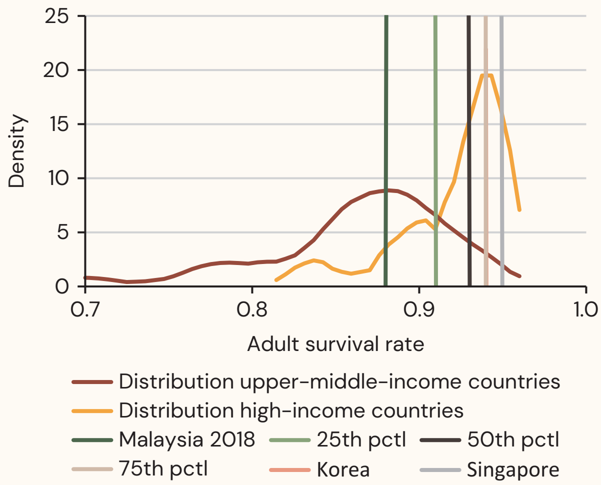
Figure 5.26: Malaysia's Stunting Rates



Source: HCI

Figure 5.27: Malaysia's Adult Survival Rates



Source: HCI

Figure 5.28: Human Capital Growth Due to Reforms

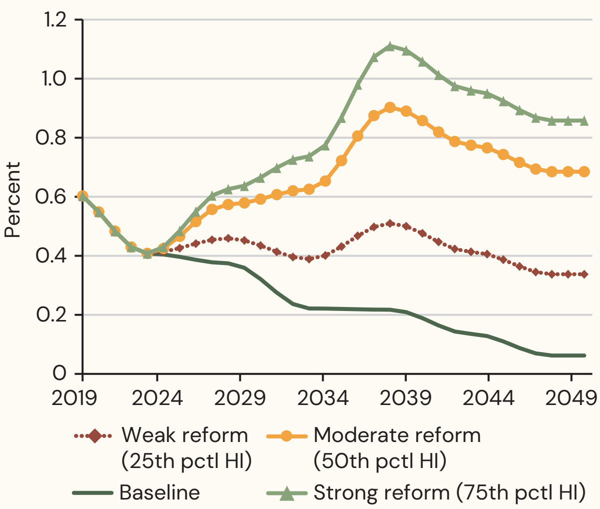
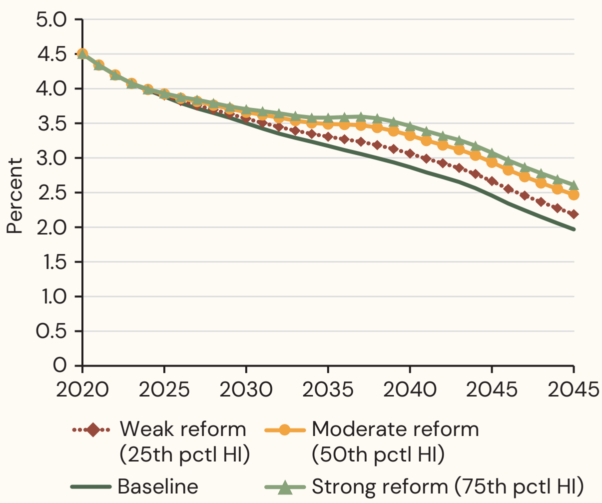


Figure 5.29: GDP Growth Due to Human Capital Reforms



Sources: Figures 5.25–5.28 from Human Capital Index; figures 5.29–5.30 from authors' calculations.

Figure 5.30: Malaysia's Human Capital Growth—Disaggregation by Components

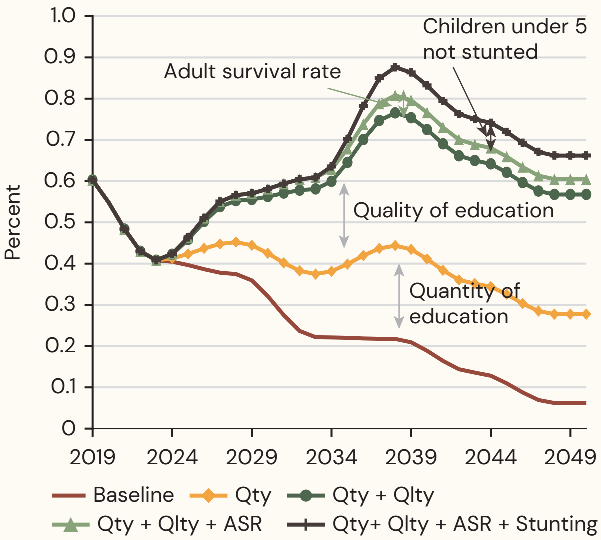
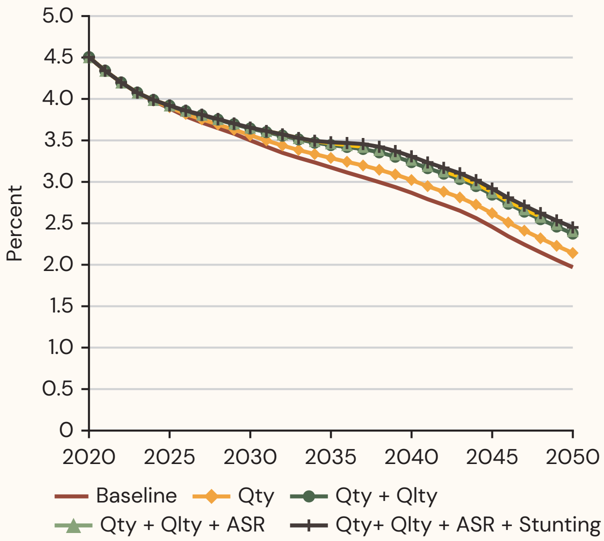


Figure 5.31: Malaysia's GDP Growth Due to Human Capital Growth by Component



Source: Authors' calculations.

of 2018, which is low in comparison to its regional peers (see figure 5.11) and also to its high-income peers (see figure 5.32). We simulate increases from the current FLFP of 55% to the 25th (weak reform), 50th (moderate reform), and 75th (strong reform) percentiles of FLFP of high-income economies, for which the number of years to reach the target is 75th (long), 50th, and 25th (short) percentiles, respectively, in the distribution of years that the high-income countries took from the Malaysia's current level (in 2018) to the target.[19] We find that these increases in FLFP boost GDP growth by about 0.15ppts, 0.30ppts, and 0.40ppts over 2020–2050, respectively, relative to the business-us-usual baseline with unchanged FLFP (figures 5.34–5.35).

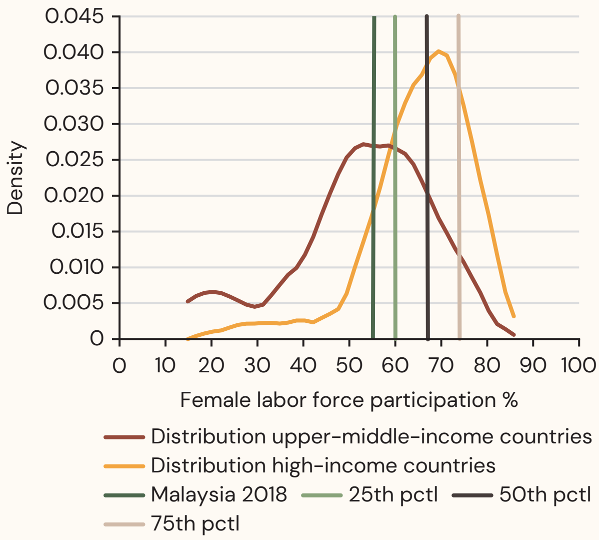
5. Combined Shocks to Generate Weak, Moderate' and Strong Reform Growth Paths

Malaysia is heading to high-income status in the next decade, and the business-as-usual baseline suggests that GDP growth will more than halve over the 2020–2050 period. More importantly for living standards, GDP per capita growth is also expected to halve over the same period. While this is common among economies making the transition to high-income status, slowing growth can—at least partially—be offset by pro-growth reforms.

In this section, we simulate the combined growth effects of a *package* of reforms affecting human capital growth, TFP growth, female labor force participation rate, and/or investment. The components of the

[19] For example, in the weak reform, the target FLFP is 62%, which is the 25th percentile among HI countries and of Croatia in 2018. For calculating a target duration to reach 62%, we identified eight high-income countries which show the path of FLFP from Malaysia's current level to the target (55% to 62%) within the time period of our database (1990–2018). Then the target duration was calculated at 27 years, which is the 75th percentile in the years the eight countries took to reach from 55% to 62%. With the same approach, the moderate reform scenario targets 69% (Spain in 2018) over 23 years, and the strong reform scenario, 74% (Netherlands in 2018) over 27 years (figure 5.33).

Figure 5.32: FLFP Distribution of High-Income Economies



Source: WDI.

Figure 5.33: FLFP Simulations

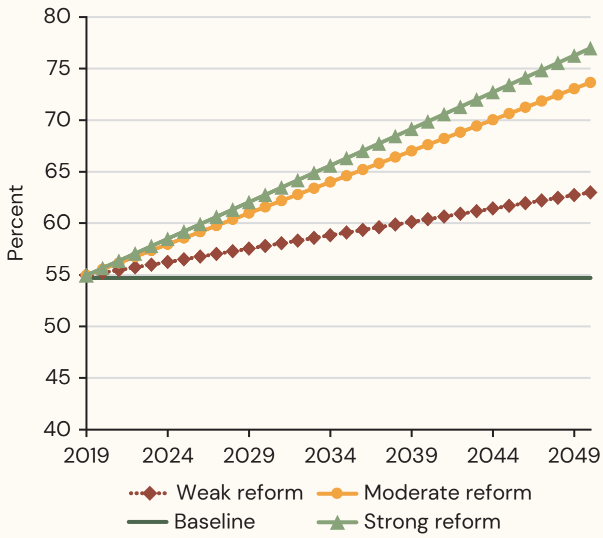


Figure 5.34: Malaysia's GDP PC Growth Due to Increases in FLFP

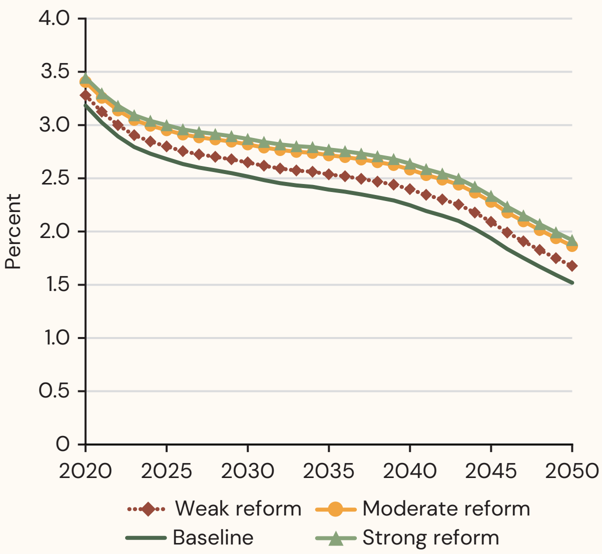
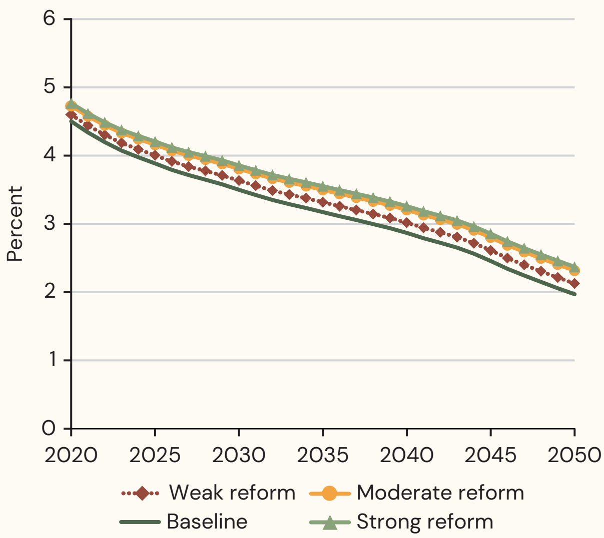


Figure 5.35: Malaysia's GDP Growth Due to Increases in FLFP



Source: Authors' calculations.

package of reforms are the same as those discussed individually in section 4; here we combine their effects. The results are shown in figures 5.36 and 5.37.

In the weak reform scenario, based on increasing the growth determinants to the 25th percentile of high-income countries (as above), growth is around 0.6ppts *lower* than the baseline in the early 2020s, but converges to the baseline by around 2040. The initial fall in growth is due mostly to lower investment rates: a fall in public investment (relative to the baseline) of around 1ppt of GDP, and a fall in private investment

Figure 5.36: **Malaysia's GDP PC Growth Due to Reforms**

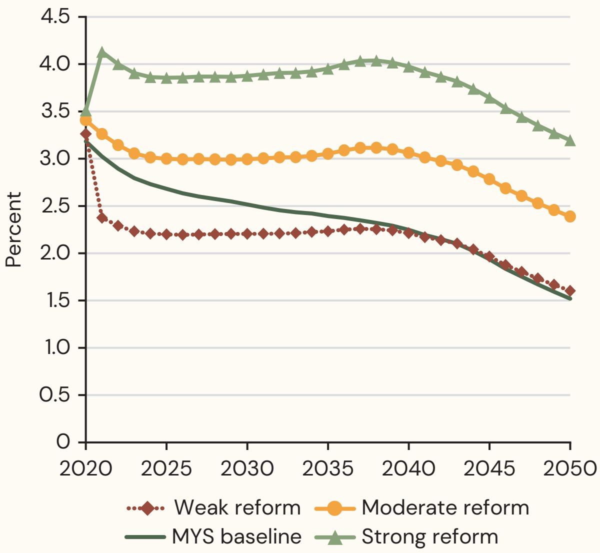
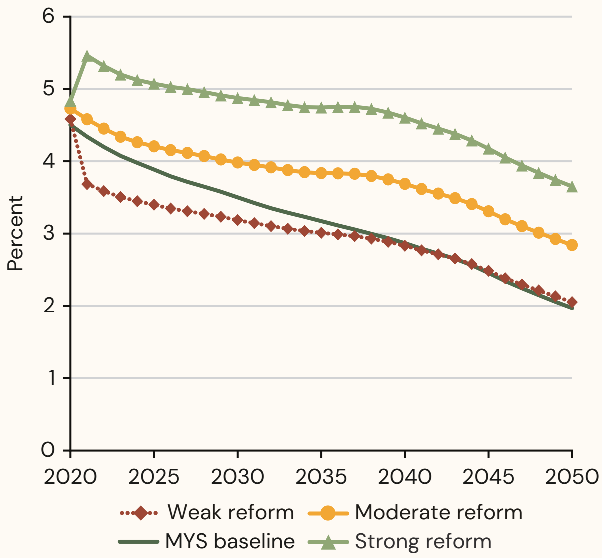


Figure 5.37: **Malaysia's GDP Growth Due to Reforms**



Source: Authors' calculations.

(relative to the baseline) of around 2ppts of GDP. These have an immediate negative effect on growth—especially the cut in private investment— given that the marginal product of private capital is initially very high. Slower TFP growth, which is lower in the weak reform scenario than the baseline, also makes a small negative contribution. The catchup in the medium term is driven mostly by human capital, where even weak reforms boost growth relative to business as usual—albeit with a lag. The human capital lag is driven by the time it takes better educated, healthier children to grow up to become more productive workers.

In the moderate reform scenario, growth is higher at all horizons and averages 0.6ppts higher over 2020–2050. Public and private investment stays constant in the moderate reform scenarios (as in the baseline), which is why the change in growth around 2020 is small. In addition, the moderate reform TFP growth is very similar to baseline, and so makes little contribution in either direction. Consequently, the boost to growth in the first 10–15 years in the moderate reform package is mostly due to higher FLFP. After that, the boost to growth increases further as today's children, with higher human capital, start to join the labor force around 2035–2040. While GDP growth does still decline, it does so at a reduced rate and the downward trend in GDP per capita growth is checked until 2040.

Finally, in the strong reform scenario, based on growth determinants at the 75th percentile of high-income countries, growth is around 1.5ppts higher than the baseline over 2020–2050. The decline in GDP growth (relative to 2020) is delayed until 2042, and GDP per capita growth is higher than its 2020 rate at almost all horizons. Growth increases initially to 5.5%, mostly based on higher private (and public) investment. Higher TFP growth and FLFP boost GDP growth as well, joined by human capital after around 2035–40. It should be noted, however, that such a path represents the most optimistic path for growth and reforms.

6. Conclusions

The main findings of the chapter can be summarized as follows. With the business-as-usual baseline, the GDP growth rate is expected to fall from 4.5% to 2.0% over the next 30 years (2020–2050), which covers the period of the country's transition to high-income status and beyond. This decline is partly due to demographics, but the other main causes are (i) a smaller contribution from private investment as private capital accumulates and its marginal product declines, and (ii) the gradual moderation in the growth rates of TFP and human capital, for which continuous improvements at a high growth rate become more difficult as their levels increase.

Under the scenario of weak reform, the GDP growth rate is expected to decrease from 4.5% to 2.0% over the next 30 years, which is similar to the result of the baseline. The impact is minimal compared to the baseline because the expected paths of growth drivers under this scenario are similar to those of the baseline. Under the scenario of moderate reform, the GDP growth rate is expected to decrease from 4.5% to 2.9%, which is around 1.5 times the GDP growth rate of the baseline in 2050. Under the scenario of strong reform, the GDP growth rate is expected to decrease from 4.5% to 3.6%, which is around 1.8 times higher than that under the baseline in 2050. Higher overall investment-to-GDP due to a better fiscal position and private investment ecosystem supports growth in the short-to-medium term, but its weakening incremental effect must be offset by other factors. The strong reform scenario clearly illustrates how the stronger contributions emanating from growth in human capital (0.28ppts growth increase with respect to the baseline, or 39% of the growth differential), TFP (0.02ppts or 30%), and female labor force participation rate (0.30ppts or 24%) can, to some extent, mitigate the diminishing returns to physical capital accumulation over the long term (7% of the growth differential in relation to the baseline).

The policy implications are derived from these results. Strong reforms are required to grow beyond what is expected based on historical trends, especially for human capital (the quantity and quality of schooling, and health), female labor force participation, and TFP. If Malaysia stays at the current level of educational quality and health (similar to the 25th percentile of high-income countries), human capital will not contribute much to economic growth. Improving human capital requires more focus on enhancing learning outcomes, improving child nutrition, and providing adequate protection through social welfare programs (World Bank 2018). Current female labor force participation is lower than the 25th percentile of high-income countries, which is the benchmark of the weak reform scenario. Increasing it requires reducing or eliminating barriers to economic opportunities for women through legal reforms, introducing more economic and societal support for parents, and addressing gender norms and attitudes that perpetuate disparities (World Bank 2019). Strong reforms to increase TFP growth require efforts from diverse stakeholders. Our study shows that the gap between Malaysia's current level (in 2018) and a target corresponding to the 75th percentile of high-income countries is relatively small for market efficiency but becomes increasingly wider for innovation, infrastructure, education, and institutions. Some of them, such as education and institutions, are expected to require two decades or more to improve to the target level of high-income economies. As these determinants are intercorrelated, sustainable collaboration and cooperation among the government, private sector, and civil society will be necessary.

Appendices and the spreadsheet-based toolkits are available online at https://www.worldbank.org/LTGM.

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Chapter 6

Analysis of Korea's Long-Term Growth Process and Lessons for Sustainable Development Policy[1]

Hyeok Jeong[2]

Abstract

This chapter analyzes Korea's growth process, not only rapid but also sustained for six decades at 6% per year. The sources of such growth were balanced among labor market demographic factors, capital investment, human capital accumulation, and productivity growth. However, the main engine of growth evolved sequentially, e.g., labor and human capital factors in the 1960s, capital deepening in the 1970s, and then productivity growth for the following periods. We found that major sources of the six-decade sustained growth were productivity growth and human capital accumulation rather than the expansion of labor force or capital investment. Counterfactual analysis of the neoclassical growth model reveals that accelerated productivity growth after the fast capital deepening was the key to the Republic of Korea's long-term growth, avoiding the middle-income trap. Appropriate calibration of the neoclassical growth model allowing time-varying transitional growth parameters explains Korea's growth experience well and provides useful lessons for sustainable development policy.

JEL Classification: O11, O47, O53, J24.
Keywords: Korea's growth experience, neoclassical growth model, sustainable development policy, middle income trap, growth accounting, productivity, human capital.

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[2] Hyeok Jeong, Seoul National University, Graduate School of International Studies, Gwanak-ro 1, Gwanak-gu, Seoul 08826, Korea. E-mail: hyeokj@gmail.com. This work was supported by the Global Facility on Growth for Development project between the World Bank Group and Korea Development Institute [PO #7179114]. We appreciate the helpful comments from Steven Pennings, Luis Serven, Jungsoo Park, audience from various conferences, and two anonymous referees. The views expressed here are those of the author, and do not necessarily reflect those of the World Bank, its Executive Directors, or the countries they represent.

1. Introduction

A casual observer of the Republic of Korea's remarkable development experience, which Lucas (1993) indeed called a "miracle", is often impressed by its rapid and compressed growth experience but often overlooks three important features of Korea's development process[3]: (i) how much adverse Korea's initial conditions were; (ii) the sustainability, not just the speed, of growth which has continued for about 60 years, overcoming various kinds of adverse initial conditions; and (iii) productivity growth, not capital deepening, is behind such sustainable development. In fact, this is exactly why Korea's development experience is valuable for other developing countries.

The list of Korea's adverse initial conditions includes almost all sorts of barriers to development, such as colonial experience, civil war, corruption, lack of physical and human resources, political instability, which are mentioned in the development literature as the critical hurdles to development for most developing countries these days. Korea was a truly devastated poor nation when it started to take off toward the miraculous growth, being unaware of what would be coming, maintaining the annual average growth rate of real gross domestic product (GDP) per capita at 6% for almost six decades.

Not all developing countries could achieve such sustainable and rapid growth after World War II, and Korea's growth experience can be a useful benchmark case for them. However, Korea's development experience per se would be of little help for the current developing countries because global environments have changed, and each developing country faces different kinds of domestic socioeconomic and historical conditions, hence different challenges and development goals. Only through the understanding of the underlying mechanisms of Korean economic growth, would Korea's successful development experience be useful. This chapter attempts to contribute to such understanding by performing two kinds of quantitative analysis. First, we decompose the sources of Korea's real GDP per capita growth via an extensive growth accounting analysis for the long-term 1960-2014 period, not only for the entire period but also for each decade, using internationally comparable data. This analysis will provide the understanding of the Korea's long-run growth process from Korea's take-off period to the recent low-growth period, which is first done in the literature of empirical studies on Korea's economic growth. It is worth mentioning that this kind of long-term growth analysis can be extended to other countries and also be compared to the results of this chapter because we use internationally comparable data.

Second, using the findings from the first decomposition analysis as building blocks, we calibrate the neoclassical growth model to Korean economy in various ways of constructing a counterfactual analysis to sort out the quantitative importance between transitional growth and long-term growth. This calibration analysis also evaluates the validity of the use of the neoclassical growth model as a growth policy prescription tool for the policy makers of developing countries, which is the World Bank's recent initiative of the Long Term Growth Model (LTGM) project.[4] The LTGM project aims to help the policy makers of developing countries design the national macroeconomic development policies from the perspective of the neoclassical growth model. By predicting the future growth paths from the desired changes of investment and/or labor market policies such as promotion of labor force participation or investment, policy makers can better envision and quantify their development goals. This kind of quantitative policy design would be a great help in articulating their policy goals and also in materializing the actual changes. Furthermore, an explicit use of

[3] Hereafter, we will simply refer to "Korea" for the Republic of Korea.

[4] The LTGM is an Excel-based tool that allows users to simulate future long-term growth for most of the world's developing and emerging economies, building on the neoclassical growth model. See chapter 1 of this volume and https://www.worldbank.org/LTGM.

a structural growth model in doing this kind of quantitative exercises is clearly beneficial. At the same time, however, calibration of the structural model is always a challenge, particularly for prediction purposes in response to policy changes. Therefore, it would be useful to see if such an exercise can in fact be applied to a previous development experience for a country which already achieved the development goals that the current developing countries are aiming for now. In this sense, the results of the application of the LTGM to Korea's development experience would deliver useful messages to other developing countries. We will discuss the appropriate calibration strategy for this purpose.

This chapter consists of the following contents. We first describe the canonical neoclassical growth model in section 2. This model will be applied to Korea's economic growth for the 1960–2014 period to identify the underlying sources of Korea's GDP per capita growth in section 3 by growth accounting analysis. Based on this analysis, we calibrate the model to Korea's economic growth in two perspectives in section 4. First, we use the model as a prediction tool for policy prescription in terms of predicting Korea's growth process, comparing the fitting performance across different calibration methods: conventional method of assuming all key growth parameters at constant values versus a method of allowing time-varying transitional growth parameters. Second, we evaluate the model as a descriptive tool to identify the influences of the transitional and long-term growth policies for Korea's long-term growth experience via various counterfactual analyses. Both types of calibration exercises illuminate the important nature of Korea's long-run growth and also the validity of the use of the LTGM for developing countries. Section 5 concludes.

2. Neoclassical Growth Model as an Accounting Framework

We consider the standard neoclassical growth model based on the aggregate production function, which was first proposed by Solow (1956) postulating the relationship between inputs of capital K_t and effective unit of labor $\tilde{L}_t$ and output Y_t at aggregate levels. We consider a standard Cobb-Douglas form for the specification of the aggregate production function, i.e., such that

$$Y_t = K_t^{1-\beta}\left(\widetilde{L_t}\right)^{\beta}, \tag{1}$$

where the parameter β corresponds to the labor share in national income account. The effective unit of labor $\tilde{L}_t$ is further decomposed into the quantity of labor L_t, the human capital per worker h_t, and the labor-augmenting technology level A_t such that

$$\widetilde{L_t} = A_t h_t L_t,$$

hence the aggregate production function is specified as

$$Y_t = K_t^{1-\beta}\left(A_t h_t L_t\right)^{\beta}, \tag{2}$$

which satisfies the canonical properties of the aggregate production function of the neoclassical growth model, i.e., (i) monotonicity, (ii) diminishing returns and (iii) constant returns to scale. In terms of per worker term, this can be represented by

$$y_t = A_t^{\beta} k_t^{1-\beta} h_t^{\beta}, \tag{3}$$

where $y_t = Y_t/L_t$ and $k_t = K_t L_t$.

Capital is accumulated according to the standard law of motion

$$K_{t+1} = I_t + (1-\delta)K_t, \tag{4}$$

where I_t denotes the capital investment and δ the depreciation rate of existing capital stock. We follow Solow's convenience assumption that the investment is determined by the exogenous investment rate γ such that $I_t = \gamma Y_t$.

Although already being well known, it is worth stating the key properties of the equilibrium dynamics for this kind of neoclassical growth model, because we use a growth accounting formula which is consistent with these properties. First, the diminishing returns property of the neoclassical growth model stabilizes the equilibrium growth dynamics, i.e., the equilibrium growth path is stable to exogenous shocks unlike the knife-edge property of the Harrod-Domar type of growth models. Second, in relation to this property, there are two kinds of growth, transitional growth and steady-state growth. The steady-state growth is the growth that is maintained in the long run, i.e., when the state of the economy grows at a constant equilibrium rate. The transitional growth is the one which is manifested when the state variable is deviated from the steady state. Solow's (1956) fundamental contribution is that he articulated the following two propositions: (i) the steady-state growth is determined only by the productivity growth, i.e., the growth of the labor-augmenting technology A_t, and (ii) the transitional growth driven by the pure capital investment effect is governed by the capital-output ratio K_t/Y_t. For an economy in the transitional growth path, the capital-output ratio increases when it is smaller than the steady-state value, while it decreases vice versa. That is, the capital-output ratio is an important barometer whether the economy is in steady state or in transition path. Note that capital stock increases even in steady state, although this is not purely driven by investment. It is easy to see that this kind of capital accumulation in steady state is not an investment effect. Suppose there is no productivity growth (no growth of A_t). Then, there will be no growth in capital stock in steady state. That is, this kind of capital accumulation is a productivity-growth-induced one. In contrast, the capital-output ratio is constant in steady state whether the productivity grows or not. These arguments suggest that genuine capital accumulation effect from investment per se, which we will call "capital deepening" effect, is captured by the capital-output ratio, not by the capital-labor ratio.

Another feature of the aggregate production function in equation (2) is that the "productivity" is specified in terms of the labor-augmenting technology rather than capital-augmenting technology or factor-neutral technology. In fact, this particular specification is adopted in all neoclassical growth models, not just for the Cobb-Douglas form. For the Cobb-Douglas form of production function, the three kinds of specification of productivity, in fact, can be relabeled into the so-called total factor productivity (TFP). However, our particular specification of technology is chosen in most of the growth literature because the stability of the growth equilibrium is achieved only when the productivity is specified in terms of the labor-augmenting technology, which is shown by Uzawa (1961). This critical proposition for the neoclassical growth model seems to be rarely acknowledged these days.

Based on the above arguments about the properties of the neoclassical growth model, we specify our aggregate production function in per worker term such that

$$y_t = A_t h_t (K_t / Y_t)^{\frac{1-\beta}{\beta}}, \tag{5}$$

which is another expression of the output per worker. From this specification, we obtain the growth accounting formula that we will use:

$$\hat{y}_t = \hat{A}_t + \hat{h}_t + \left(\frac{1-\beta}{\beta}\right)\widehat{\left(\frac{K}{Y}\right)}_t, \tag{6}$$

where the "hat" notation denotes the growth rate of the corresponding variable, e.g., $\hat{y}_t \equiv \dfrac{dy_t / dt}{y_t}$. This approach of growth accounting for the neoclassical growth model with augmenting human capital was first adopted by Mankiw, Romer, and Weil (1992).[5] Klenow and Rodriguez-Clare (1997) and Jones (2002) also use this formula of growth accounting. Since these influential works on growth empirics, this specification of growth accounting has become standard.

Such articulation of the consistency between theory and empirics is important for this chapter, because the distinction between steady-state growth and transitional growth matters in the counterfactual analysis via comparing various types of calibration of the neoclassical growth model to Korea's growth experience, which we will perform after the growth accounting analysis. The formula in equation (6) decomposes the growth of output per worker into differentiated sources, i.e., the steady state growth (represented by $\hat{A}_t$) and the transitional growth (represented by $\left(\frac{1-\beta}{\beta}\right)\widehat{\left(\frac{K}{Y}\right)_t}$), consistently with the neoclassical growth theory. Whether to consider the human capital effect as the steady state growth or the transitional growth depends on how to specify the human capital accumulation dynamics. Mankiw, Romer, and Weil (1992) specifies the human capital dynamics subject to diminishing returns and consider its effect as transitional growth. In earlier work, Lucas (1988) also incorporates human capital into the neoclassical growth model and shows that steady state growth is possible through the human capital due to its spillover effect at aggregate level, despite the presence of the bounded learning at individual level. Given this possibility, we consider the human capital accumulation, $\hat{h}_t$ in (6), as a source of steady state growth, with caution.

The conventional growth accounting formula that decomposes growth mechanically into factor accumulation effects and total factor productivity (TFP), or the Solow residual, is given by

$$\hat{y}_t = \widehat{TFP}_t + \beta\hat{h}_t + (1-\beta)\hat{k}_t, \tag{7}$$

where the conventional total factor productivity (TFP) variable TFP_t is measured as

$$TFP_t = \frac{Y_t}{K_t^{1-\beta}(h_t L_t)^{\beta}} = A_t^{\beta} \tag{8}$$

so that

$$\widehat{TFP}_t = \beta\hat{A}_t. \tag{9}$$

This shows that the conventional TFP growth is a scaled-down version of our productivity growth measure by the factor of labor share. The magnitude of the human capital growth effect from the conventional growth accounting is smaller than our human capital growth effect also by the factor of labor share. In consequence, the magnitude of the capital accumulation effect for growth measured by the capital-labor ratio following the conventional way is always higher than our measure of capital deepening effect for growth. This is not surprising because the capital accumulation effect in the conventional growth accounting formula includes both the investment-driven effect and the productivity-induced effect, as we argued above. That is, the capital accumulation effect measured by the growth in the capital-labor ratio as in conventional growth accounting always overestimates the genuine effect of capital investment. This overestimation of capital accumulation effect is avoided in our growth accounting formula in equation (6).

The typical measure of the level of development or national welfare is the GDP per capita $y_{p,t} \equiv Y_t/N_t$ (where N_t is the total population size) rather than the GDP per worker $y_t \equiv Y_t/L_t$ above. GDP per capita differs from GDP per worker by the two demographic compositions of the labor market: (i) the labor force participation

[5] David (1977) is the early version of this approach without human capital.

rate $S_{E,t} \equiv L_t/N_{L,t}$ and (ii) the working-age population share $S_{W,t} \equiv N_{L,t}/N_t$, where $N_{L,t}$ is the working-age population (age group of 15–64) size, and L_t is the labor force size [6] such that

$$Y_{p,t} = S_{w,t}S_{E,t}y_t, \tag{10}$$

and in growth terms

$$\widehat{y_{P,t}} = \widehat{S_{W,t}} + \widehat{S_{E,t}} + \hat{y}_t.$$

Our empirical target is to understand how this national welfare or development level changes over time. Park and Shin (2011) also consider this kind of decomposition incorporating demographic aspects for growth, mainly focusing on changes in the working-age population share.

Combining the output per worker growth accounting in equation (6) with this GDP per capita growth decomposition, we have our final growth accounting formula

$$\widehat{y_{P,t}} = \widehat{S_{W,t}} + \widehat{S_{E,t}} + \hat{A}_t + \hat{h}_t + \left(\frac{1-\beta}{\beta}\right)\widehat{\left(\frac{K}{Y}\right)_t}. \tag{11}$$

3. Analysis of Korea's Economic Growth

3.1 Data

Equation (11) is our framework of accounting for Korea's economic growth and also in assessing the validity of the calibration of neoclassical growth model to Korea's growth experience. The latter analysis can deliver lessons for the policy makers of other developing countries who would like to apply the neoclassical growth model in designing growth policies. To measure this equation, we use the following data series for our sample period 1960–2014, (their sources are in brackets): (1) total population size [World Development Indicators (WDI)] for N_t, (2) working-age population share [WDI] for $S_{w,t}$, (3) labor force participation rate [WDI] for $S_{E,,t}$, (4) real GDP at constant 2011 national prices (in 2011 million US$) ["rgdpna" in Penn World Table version 9.0 (PWT 9.0)] for Y_t, (5) capital stock at constant 2011 national prices (in 2011 million US$) ["rkna" in PWT 9.0] for K_t, (6) human capital per worker ["hc" in PWT 9.0] for h_t, (7) labor force size [WDI] for L_t, (8) labor share ["labsh" in PWT 9.0] for β, (9) capital depreciation rate ["delta" in PWT 9.0] for δ, (10) labor-augmenting technology level [calculated from equation (2)], and (11) investment [calculated using investment rate data "csh_i" from PWT 9.0]. The value of the average labor share which we calibrate for the parameter β is 0.602. The value of the average depreciation rate which we calibrate for the parameter δ is 0.053.[7]

Our use of the data has two significant features. First, this is the first chapter that performs the growth accounting together with a counterfactual calibration analysis by combining the internationally available data sources such as the Penn World Table (PWT) 9.0 and the World Development Indicators (WDI) rather than relying on country-specific national income statistics. This became possible because there were

[6] We use labor force data from the World Development Indicators (WDI) for L_t to maintain consistency with the data use protocol of the LTGM project so that there are possible differences in labor force participation rate between the national sources and the WDI. Furthermore, using labor force instead of employment data may generate the different growth rate of $\widehat{S_{W,t}}$. However, using the national source data, we find that labor force participation rate and employment rate tightly co-move with each other, and the growth rates of $\widehat{S_{W,t}}$ between the two measures differ only by 0.1% for the sample period.

[7] The original data source of the WDI labor variables such as working-age population and labor force participation rate is the International Labor Organization (ILO) Statistics. The labor share and the capital depreciation rate variables are time-varying in PWT 9.0, and we take the time-series averages during our sample period 1960–2014.

important improvements in internationally comparable measurements of output, production factors, and factor shares in the PWT 9.0, which were released recently in 2016. Second, this chapter is the very first attempt to quantitatively characterize the long-run process of Korea's growth from the take-off period to the recent new normal era of growth slow down (1960–2014 period) so that we can assess the evolution of Korea's growth process from the neoclassical growth perspective. Obviously, the simple neoclassical growth perspective won't be able to fully capture the complex nature of Korea's growth process. At the same time, however, there is no doubt that the accounting framework of the neoclassical growth models (which is perhaps the most important strength of this class of growth models) provides us with the most critical groundwork for understanding the nature of the growth process. The use of the internationally comparable long-run data is first done in assessing Korea's growth process by this chapter. This contributes not only to understanding Korea's growth process, but also to providing a benchmark reference study for other developing countries in designing their growth policies, because the journey of Korea's economic development started from the similar starting point.

3.2 Accounting Analysis of Korea's Long-Run Growth Process

Applying our accounting framework in equation (11) to the above data, we decompose Korea's growth of GDP per capita for the 1960–2014 period by constructing counterfactual GDP per capita measures as follows. Combining equations (5) and (10), we express the GDP per capita such that

$$y_{P,t} = S_{W,t} S_{E,t} A_t \, (K_t / Y_t)^{\frac{1-\beta}{\beta}} h_t. \tag{12}$$

In order to isolate the contribution of productivity growth to GDP per capita growth, we fix the values capital-output ratio, human capital per worker, working-age population share, and labor force participation rate at the 1960 values and vary only the labor-augmenting technology level as in the data. That is, the counterfactual GDP per capita measure due to the productivity change is

$$y^{A}_{P,t} = S_{W,1960} S_{E,1960} A_t \, (K_{1960} / Y_{1960})^{\frac{1-\beta}{\beta}} h_{1960}$$

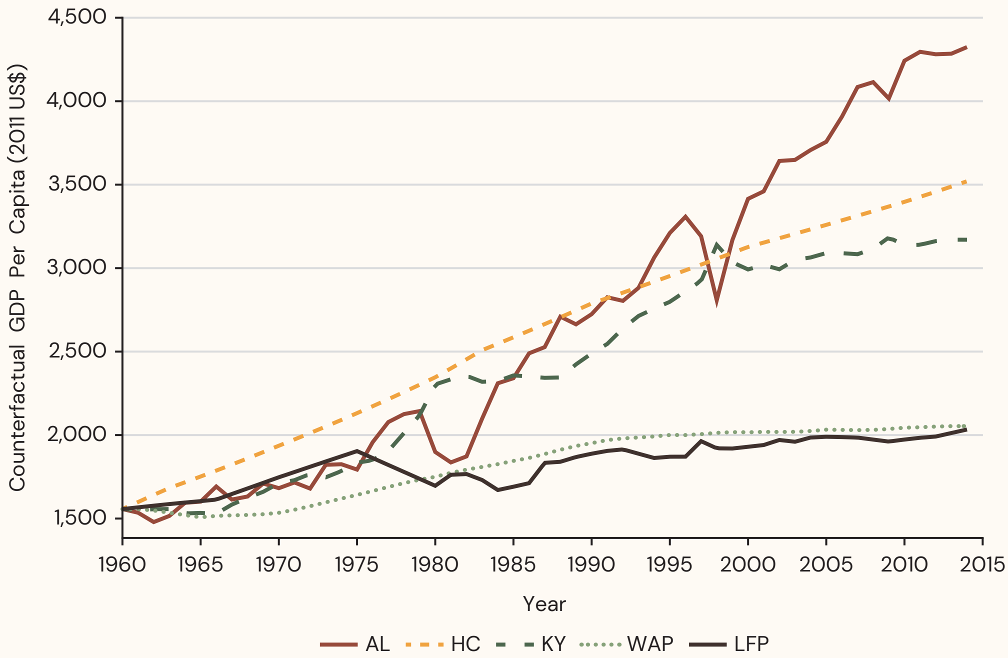
and the growth rate of this counterfactual measure is

$$\widehat{y^{A}_{P,t}} = \widehat{A_t}$$

We can similarly construct counterfactual measures of GDP per capita due to the changes of other components. Figure 6.1 plots those counterfactual GDP per capita measures for each of the five components of productivity (labeled as "A"), human capital per worker (labeled as "HC"), capital deepening (labeled as "K/Y"), working-age population share (labeled as "WAP"), and labor force participation rate (labeled as "LFP"). Table 6.1 summarizes the growth rates of the actual and the above counterfactual measures of GDP per capita for the entire period as well as for each of the sub-period decades (1960s, 1970s, 1980s, 1990s, and 2000s) and the remaining 2010–2014 period.

Figure 6.1 and Table 6.1 reveal interesting features about Korea's economic growth for the last 55 years, which are not well recognized in the literature. First, it turns out that the largest contributing component to Korea's real GDP per capita growth during the 1960-2014 period is the productivity growth rather than each of the factor growth. The contribution of the productivity growth ($\hat{A}_t$) is 1.9% each year on average. The contribution of the human capital growth ($\hat{h}_t$) is 1.5% each year on average. The contribution of the capital deepening $\left(\left(\frac{1-\beta}{\beta}\right)\widehat{\left(\frac{K}{Y}\right)_t}\right)$ is 1.3% each year on average. The contributions from the labor market demographic changes are 0.5% from the increase in working-age population share ($\widehat{S_{W,t}}$) and also 0.5% from the increase in labor force participation rate ($\widehat{S_{W,t}}$) so that the combined contribution from

Figure 6.1: Counterfactual Measures of GDP Per Capita



Note: (1) Each line represents the counterfactual path of GDP per capita from the isolated growth of each variable. (2) "AL" Productivity growth of labor-augmenting technology, "HC" Human capital growth, "KY" Capital deepening, "WAP" Changes of working-age population share, "LFP" Changes of labor force participation rate.
Source: WDI and PWT 9.0

Table 6.1: Decomposition of Sources of Korea's Growth of GDP per Capita (%)

Period	Total	WAP	LFP	A	HC	K/Y	TFP
1960–2014	5.9	0.5	0.5	**1.9**	1.5	1.3	1.1
1960–1970	5.0	–0.1	1.2	0.8	**2.2**	1.0	0.5
1970–1980	7.4	1.3	–0.3	1.2	1.9	**3.0**	0.7
1980–1990	8.6	1.1	1.1	**3.7**	1.7	0.8	2.2
1990–2000	6.0	0.3	0.2	**2.3**	1.2	1.9	1.4
2000–2010	3.9	0.1	0.2	**2.2**	0.8	0.5	1.3
2010–2014	2.5	0.1	0.8	0.5	**0.9**	0.3	0.3

Note:
(1) Each column represents the contribution of each variable to the annual average growth rate of GDP per capita.
(2) "Total" Total growth of real GDP per capita, "WAP" Contribution of changes of working-age population share, "LFP" Contribution of changes of labor force participation rate, "A" Contribution of productivity growth, "HC" Contribution of human capital accumulation, "K/Y" Contribution of capital deepening, and "TFP" Total factor productivity growth (which is equal to the labor share times column "A").
Source: PWT 9.0 and WDI

the labor market demographic changes is 1.0%. This feature of productivity-driven growth of Korea may come at a surprise, because the typical image for Korean economic growth for both external observers and internal policy makers is investment-driven. However, recalling Korea's sustained growth for about six decades, this should not be a surprise from the neoclassical growth perspective, which states that long-run growth is possible only through productivity growth. Regarding the speed of growth, there were many developing countries which experienced growth as rapid as Korea during 1960s, 1970s, or 1980s. Such examples include Mexico, Zambia, Gabon, and Mauritius. However, the rapid growth of those countries lasted only 10 to 20 years. The fundamental reason why Korea could maintain the 6% growth per year for about six decades unlike those countries seems to be no longer puzzling. Korea's growth experience provides an empirically valid prescription for the importance of productivity for sustainable development *à la* neoclassical growth models.

It is worth noticing that this contribution ordering among growth components depends on our way of formulating growth accounting as in equation (6). Using the conventional growth accounting formula in equation (7), the TFP contribution is 1.1%, human capital contribution is 0.9%, and capital per worker contribution is 2.8%, so that the contribution measures for both productivity and human capital decrease while the capital contribution measure increases, comparing to the results of our accounting method. However, as we argued in section 2, part of the 2.8% contribution of capital accumulation per worker is due to the productivity growth, hence the contribution of capital investment is overstated. Filtering such induced capital accumulation effect out, the contribution of the capital investment turns to 1.3%. Furthermore, as we argued again in section 2, the steady-state growth rate is determined by our productivity growth measure $\hat{A}_t$, not by the TFP growth. Bearing this in mind, however, we provide the conventional TFP growth measure in the last column of table 6.1 for a reference.

The second interesting feature is that despite the above differences of contribution ordering, the magnitudes of contribution are substantial for all components, ranging from 1.0% to 1.9%, none of which are negligible. That is, the sources of growth are *well balanced* among productivity, human capital, capital deepening, and labor market demography during the long-run process of Korea's economic growth, without any of which the annual growth rate of 5.9% could not have been realized.

Table 6.1 provides the decade-specific growth accounting results as well. Comparing these results across decades, we find that the major contributing components change over time. In the initial development stage of the 1960s, human capital growth was the major driving force for Korea's growth, 2.2% each year on average. Combined labor market demographic effects contributed to increasing GDP per capita by 1.1% each year in the 1960s, which is the second largest contributing component in 1960s. Interpreting the human capital as quality of labor and labor market demographic changes as quantity of labor, combined labor-related growth contributed to growth by 3.3% each year in the 1960s. That is, Korea's growth in the 1960s period is labor-driven.

In the 1970s, however, capital deepening was the main engine of growth at 3.0% each year on average. The capital deepening effect dropped remarkably to 0.8% in the 1980s, surging back to 1.9% in the 1990s, and then diminished to 0.5% for the 2000s period and further to 0.3% for the 2010–2014 period. The 1970s was the period when Korean economy made a dramatic transformation into a modern economy by the export-oriented industrial policies and infrastructure building, which perhaps created the typical image of Korea's growth. This laid a solid physical foundation for the growth to follow.

For the remaining three decades of the 1980s, 1990s, and 2000s, productivity growth was the main engine of Korea's growth. The productivity growth alone contributed to increasing the GDP per capita by 3.7% per year on average in the 1980s, 2.3% in the 1990s, and 2.2% in the 2000s. The contribution shares of the productivity growth out of the total growth of the GDP per capita were 43%, 38%, and 56% during the 1980s, 1990s, and 2000s, respectively.

Summing the above comparison of the decade-specific growth accounting results, we find that Korea's growth shows a sequential pattern in terms of the main engine of growth, first labor-human-capital-driven, second capital-driven, and then productivity-driven. In particular, the productivity-driven growth lasted for three decades, followed by the significant accumulation of human and physical capital. This sequential pattern is an important feature of Korea's growth, which was not acknowledged well in the literature. Furthermore, this finding delivers an important lesson for growth policy design. The sequential feature of Korea's growth experience suggests that choosing the right sequence of focal growth policies may matter for making the growth rapid and sustainable: initial growth policy focusing on promotion of labor participation and human capital investment (for creating the productive manpower of the economy), then focusing on promotion of capital investment (for laying physical foundation of the economy), and then shifting focus to productivity enhancing growth policies (for sustaining growth). This may explain why Korea did not fall into the so-called middle-income trap.[8]

Table 6.1 delivers another noticeable pattern of Korea's recent growth. From the neoclassical growth theory perspective, the capital deepening effect, i.e., the changes in capital-output ratio indicate how far or near the economy is to the steady state, because the capital-output ratio stays constant in a steady state. The changing pattern of the capital deepening effects over time from table 6.1 seems to suggest that the Korean economy is approaching to steady state quite quickly. After 2010, the capital-output ratio has changed little, indicating that the Korean economy may be near the steady state. During this recent period (2010–2014), the productivity growth dropped to 0.5% from the 2.2% of the 2000s period. This may reflect the 2008–2009 global financial shock or perhaps the starting of the emergence of accumulated structural problems. This chapter is silent about the causes of this sudden drop of productivity growth. However, it is worth noticing that such a sudden drop of productivity growth happened when we observe a symptom showing that Korean economy is near the steady state (little change in capital-output ratio). Furthermore, for the 2010-2014 period, the largest contributing components to growth are labor related: human capital growth (0.9%) and the increase in the labor force participation rate (0.8%). In particular, the increase in the labor force participation rate is a big reversal of the trend. During the recent two decades of 1990-2010, the contribution of labor force participation has been only 0.2%. This contribution surged back to the pre-1990 level. In fact, the composition of contributing shares of growth components for the 2010-2014 period is a déjà vu of those of the 1960s period. All these symptoms are indeed concerning because they may be a presage of the starting of long-run stagnation. It may be too early to conclude that the Korean economy indeed entered into a long-run low growth because the duration of this period is only four years. However, these features were never observed for the five-decade growth experience of Korea before 2010, and Korea does need to pay attention to this change. At the same time, productivity growth is not predetermined and there still exist ample opportunities of promoting productivity growth for Korea. In this sense, the Korean economy seems to be at slippery slope for her next stage of development.

4. Calibration of Korea's Economic Growth

4.1 LTGM of the World Bank

We used a neoclassical growth model in accounting for Korea's economic growth in the previous section. Another way of using the same model is for policy makers to infer the necessary policies regarding the parameter values of the model to achieve the pre-set growth goal in the future. This way of utilizing the neoclassical growth model is recently labeled as the "Long Term Growth Model (LTGM)" approach by the World Bank for the purpose of helping the policy makers design national growth policies. The model can be used as a simulation device for future growth if we can make a reasonable conjecture about or target some key parameter values of the model that will govern in the future.

In terms of contents of the model, the World Bank's basic LTGM (chapter 1) is just the same as the neoclassical growth model in section 2. How to use such a model for simulation or policy design purposes depends on the way the model is calibrated. This kind of calibration is not an easy exercise because we need to calibrate the model to fit the future that we do not observe at the moment of calibration. The analysis of

8 See Eichengreen, Park, and Shin (2012) for the recent discussion on the empirical evidence of middle-income trap.

Korea's economic growth in section 3 can be utilized in finding the right ways of calibrating the neoclassical growth model in the following sense. Suppose there were policy makers in the past in Korea, say in the year 1970, who wanted to predict what would happen to GDP per capita growth after 1970 and the only available information set was the data for the 1960–1970 period. Then, we may ask what the best way would be for them to calibrate the underlying parameters of the model. We can answer this question because, unlike the fictitious policy makers in 1970, we in fact know what actually happened after 1970 in Korea, so we can evaluate the calibration method by evaluating the prediction performance against the actual data. We can quantitatively compare the gaps between the model predictions and actual data ex post across different calibration methods.

We find that it is important to take the transitional growth parameters (such as investment rate and labor market demographic factors) as time-varying rather than as constant as is done in typical calibration exercises of neoclassical growth models, while the prediction gap of assuming constant values for the long-run growth parameters (such as human capital growth or productivity growth). Related, we also find that the prediction performance of the conventional calibration method (assuming constant values for key parameters) depends on the stage of development. The model with conventional calibration method works very well for Korea when prediction time is 1990, while it performs poorly from the start when prediction time is 1970 or 1980. This implies that the application of the conventional calibration of the neoclassical growth model should be done with more care, the farther the economy is from the steady state. For instance, during the initial stage of development after take-off, the target growth rate is not likely to be maintained by the policy of a one-time promotion of investment rate, which is a frequent mistake made by the policy makers in developing countries. The regression to the growth rate prior to such one-time investment policy is the theoretical consequence of the diminishing returns property of the neoclassical growth model. Korean growth experience indeed confirms this property empirically. In other words, it is important to continue to promote investment in order to maintain or accelerate growth during the catchup period. However, after the economy enters into a mature stage of development (after 1990s in case of Korea), such an effect dwindles. In the following subsection, we will fully characterize the hidden interactions among parameters of the model.

4.2 Objects of Calibration

We first need to determine the set of parameters to calibrate. The GDP per capita at period t is as in equation (12)

$$y_{P,t} = S_{W,t} S_{E,t} A_t \left(K_t / Y_t\right)^{\frac{1-\beta}{\beta}} h_t,$$

and the gross growth rate of the GDP per capita between period t and $t + 1$ is

$$\frac{y_{P,t+1}}{y_{P,t}} = \Lambda_{t+1}^{\beta} \left[\frac{\gamma_t \dfrac{Y_t}{K_t} + (1-\delta)}{1+\hat{N}_{t+1}} \right]^{1-\beta} \tag{13}$$

where

$$\Lambda_{t+1} = \left(1+\hat{S}_{W,t+1}\right)\left(1+\hat{S}_{E,t+1}\right)\left(1+\hat{A}_{t+1}\right)\left(1+\hat{h}_{t+1}\right),$$

γ_t is the investment rate at period t, and $\hat{N}_{t+1}$, $\hat{S}_{W,t+1}$, $\hat{S}_{E,t+1}$, $\hat{A}_{t+1}$, and $\hat{h}_{t+1}$ are the growth rates of population, working-age population share, labor force participation rate, productivity, and human capital between periods t and $t + 1$, respectively. The growth equation (13) clarifies two things. First, the growth rate of GDP per capita increases in investment rate γ_t, but this growth effect decreases in K_t/Y_t, i.e., the capital-output ratio of the base year. The latter decreasing growth effect from investment captures the diminishing returns property of the neoclassical growth model. Second, it increases in growth rates of working-age population, labor force participation rate, productivity, and human capital but decreases in population growth rate.

Now, in order to simulate the growth path using equation (13), we need to select the parameters $(1-\beta,\delta)$ and to calibrate the growth rates of $\hat{N}_{t+1}$, $\hat{S}_{W,t+1}$, $\hat{S}_{E,t+1}$, $\hat{A}_{t+1}$, and $\hat{h}_{t+1}$. When we substitute these growth rates with the actual data, we will get the precise growth rate. For the purpose of simulation, we should choose a way to calibrate the growth rates of these five growth variables at period $t+1$ as well as the time-invariant parameters $(1-\beta)$ and δ from the observed data. Furthermore, to apply the growth equation (13) to the next period at period $t+2$, we need to calibrate γ_{t+1} also. Typical neoclassical growth models assume that $\hat{A}_{t+1}$ and $\hat{N}_{t+1}$ are constant for all periods, but they are silent about the changing rates of γ_{t+1}, $\hat{S}_{W,t+1}$, $\hat{S}_{E,t+1}$ and $\hat{h}_{t+1}$. For γ_{t+1}, $\hat{S}_{W,t+1}$ and $\hat{S}_{E,t+1}$, we cannot make the non-zero constant growth assumption because they are "share" variables which are upper-bounded. Thus, we need to choose a way to predict the path for γ_{t+1}, $S_{w,t+1}$, and $S_{E,t+1}$ during the targeted future period for the simulation purpose. Furthermore, these three variables are labeled as "time-varying policy parameters" which would change depending on demographics and policies.

For the human capital growth $\hat{h}_{t+1}$, the original Solow (1956) model is silent because it simply abstracts the human capital away. Mankiw, Romer and Weil (1992) augmented human capital to the Solow (1956) model, assuming the diminishing returns property for the human capital, hence it is not a source of long-run growth. In contrast, Lucas (1988) augmented human capital to the same Solow (1956) model but postulated it as a source of long-run growth due to the linear dynamics and spillover effects of human capital at the aggregate level. We are open to these two possible theoretical formulations and take the choice between the two formulation of human capital dynamics as an empirical question. Jeong (2017) shows the shape of the trend of the human capital per worker is rather close to linear than to concave, despite the incorporation of the diminishing returns of schooling in measuring human capital as in Hall and Jones (1999). Based on the above arguments, we categorize human capital growth as a similar kind of parameter to productivity growth at least for the sample period of this study, although the underlying dynamics of human capital would be different from productivity dynamics. However, the measurement of human capital from schooling only should be taken with caution.

4.3 Calibration 1: Status-quo Simulation Approach

To evaluate the neoclassical growth model as a simulation tool as the World Bank's LTGM project does, we would like to vary the calibration method and compare the patterns as well as the performance of the prediction of the model to seek the best way to choose the calibration objects, i.e., the future growth rates $\left(\hat{N}_{t+1},\hat{A}_{t+1},\hat{h}_{t+1}\right)$ and the time-varying policy parameters $(\gamma_{t+1}, S_{w,t+1}, S_{E,t+1})$, in order to simulate the growth path of GDP per capita. Regarding the labor share and the depreciation rate parameters, we will fix them at the same values as in the decomposition analysis of the actual Korean economy in section 3.[9]

The first and the most straightforward way of calibration is to simply follow the canonical neoclassical growth model, where the productivity and population grow at constant rates $\hat{A}_{t+1}=g_A$, $\hat{N}_{t+1}=g_N$ for all periods. We take similar constant growth rate assumption for the human capital as well such that $\hat{h}_{t+1}=g_h$ for all periods, based on the empirical observation above. The canonical neoclassical growth model also assumes that the investment rate is constant such that $\gamma_{t+1}=\gamma_t=\gamma_0$. This assumption of "constant rates" in fact can be a reasonable one when the economy is near the steady state and the economy grows close to the

[9] To recall, $1-\beta=0.602$ and $\delta=0.053$.

Table 6.2: Calibrated Parameter Values from Status-quo Approach

Simulation	g_A	g_h	g_N	γ_0	$S_{W,0}$	$S_{E,0}$	PPP real income (2011 US$)
Pred_70	0.8%	2.2%	2.6%	0.27	0.54	0.56	1,466 (1960s)
Pred_80	1.2%	1.9%	1.7%	0.37	0.61	0.59	3,844 (1970s)
Pred_90	3.7%	1.7%	1.2%	0.35	0.68	0.61	7,688 (1980s)

Note: "g_A" Annual growth rate of productivity of labor-augmenting technology, "g_h" Annual growth rate of human capital per worker, "g_N" Annual growth rate of population, "γ_0" Investment rate, "$S_{W,0}$" Working-age population share, and "$S_{E,0}$" Labor force participation rate.
Source: PWT 9.0 and WDI

balanced growth path, along which the growth rates are determined mainly by the fundamental parameters of technology and preferences. A consistent way of calibrating the labor market demographic factors with this "steady-state assumption" is to choose that $S_{w,t+1} = S_{w,t} = S_{w,0}$ and $S_{E,t+1} = S_{E,t} = S_{E,0}$ (so that $\hat{S}_{W,t+1} = 0$ and $\hat{S}_{E,t+1} = 0$) for all periods.

Suppose that a policy maker in Korea made this set of "steady-state assumptions" in 1970, and then applied the benchmark growth model to simulate the GDP per capita for the future period of 1971–2014. Suppose that the data available for this policy maker in 1970 are the 1960–1970 period data. Once deciding to take the "steady-state" approach, the best way to calibrate the constant growth rates of g_A, g_h, and g_N would be to form an *adaptive expectation* such that the constant growth rate parameters would be the annual average growth rates of the corresponding variables for the data-available period, i.e., the 1960–1970 period. In selecting the constant values for the investment rate, working-age population share, and labor force participation rate, we may want to take the average values for the past sample period to smooth out the shocks. However, if taking the averaging period too long, the average values would not represent the true values of the parameters for the simulation period. Thus, the average values for the initial five-year period prior to the starting date of simulation, for example, the 1966–1970 period values for the 1970 simulated prediction, are to be used to calibrate the investment rate, working-age population share, and labor force participation rate.

We can repeat the above simulation exercise by changing the prediction year from 1970 to 1980 (using the 1970–1980 data) or to 1990 (using the 1980–1990 data) using the same calibration method. Comparison of the three sets of prediction results would be informative because the Korean economy has evolved from a transition economy toward a steady-state economy. The calibrated values for the three sets of simulated prediction exercises, labeled as "Pred_70", " Pred_80," and " Pred_90," respectively for the 1970, 1980, and 1990 simulations by the above steady-state calibration method are summarized in table 6.2. For the purpose of referencing with other countries, in table 6.2, we also indicate the average purchasing-power-parity (PPP) adjusted real GDP per capita level for each period when the parameter values of γ_0, $S_{w,0}$, and $S_{E,0}$ are chosen.[10] For example, Korea's average PPP-adjusted real income level was US$1,466 in the 1960s when the investment rate was 0.27, working-age population share was 0.54, and the labor force participation rate was 0.56.

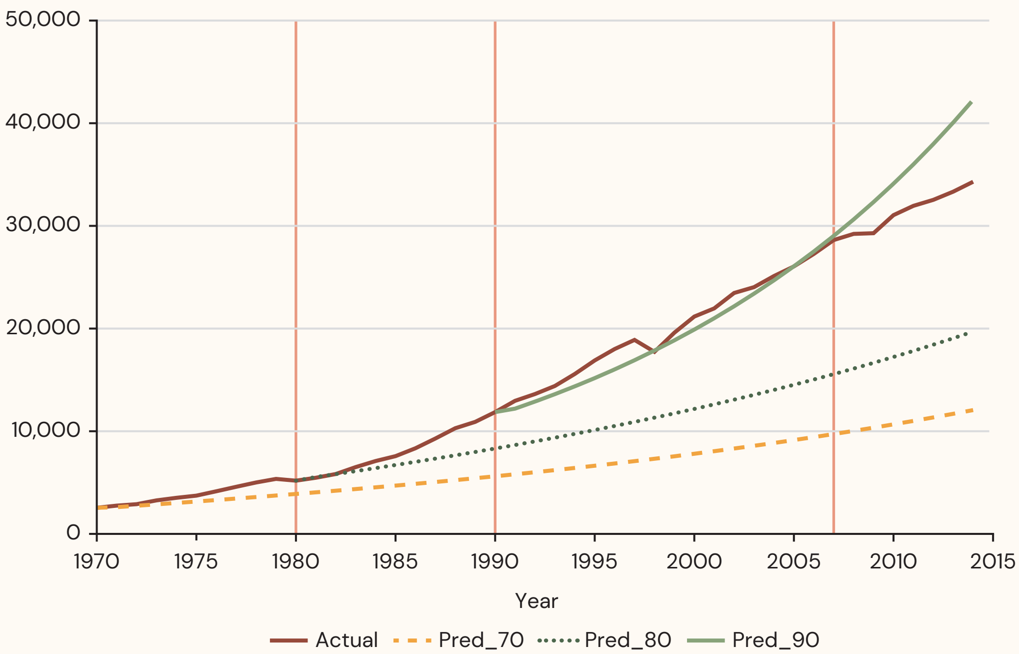
Figure 6.2 compares the predicted paths of GDP per capita of the three simulations (similarly labeled as in table 6.2), overlaid with the actual path (labeled as "Actual"). This comparison illuminates important features of the LTGM as a simulated prediction device as follows.

[10] Note that this real income measure is obtained from the "rgdpe" in PWT 9.0 divided by the WDI population data, hence it is different from our GDP per capita measure which is calculated from the "rgdpna" in PWT 9.0. In table 6.2, we use the "rgdpe" measure to facilitate the cross-country comparison of development level.

First, notice that the "Pred_70" simulation underpredicts the GDP per capita as shown in figure 6.2. It fits only the very beginning-of-period data, i.e., for the 1971–1973 period. The prediction diverges way below the actual one afterwards. This result is not a surprise because the investment rate, working-age population share, and labor force participation rate all increased during the 1960s, hence the five-year average values underestimate the future values. Furthermore, the investment rate and the working-age population share further increased in the 1970s compared to the 1960s values. The investment rate got stabilized after the early 1980s, and the increase of the working-age population share also slowed down after the 1990s. The labor force participation rate continues to show an increasing trend, except for the substantial dip during the 1977–1986 period. Furthermore, Korea's population growth rate has fallen monotonically during the entire sample period from 3.0% in the 1960 to 0.4% in 2014. All these changes have increasing effects of GDP per capita, which are not captured by the current calibration method. The growth rate of human capital decreased after the 1990s, but the magnitude of decrease is small, much smaller than the decreasing rate of capital deepening. The productivity growth rate has been more or less constant during the sample period. Thus, the current calibration method is a reasonable one regarding productivity growth and human capital growth. In sum, the underprediction of the Pred_70 using the steady-state cum status-quo approach calibration method seems to be mainly due to the assumptions of the constant rates of investment, working-age population, and labor force participation.

Observing the "Pred_80" simulation, we get similar results, although the fitting performance improves over the "Pred_70" simulation. In contrast, the 1990 prediction, which uses the 1980s data, fits the data very closely during the 17-year period (1991–2007), and then the model overpredicts the GDP per capita after 2008 with an increasing gap. The main reason behind the good fit for the 1991–2007 period is that there were no clear trends for the investment rate, despite its fluctuations, so that the capital-deepening effects are well captured by the constant investment rate assumption during this period. The overprediction of the

Figure 6.2: Comparison of Predictions from Different Simulations



Note: (1) Each line represents the actual or the predicted path of GDP per capita at different starting date of simulation. (2) "Actual" Actual GDP per capita, "Pred_70" Predicted GDP per capita in the year 1970, "Pred_80" Predicted GDP per capita in the year 1980, and "Pred_90" Predicted GDP per capita in the year 1990.
Source: WDI and PWT 9.0

"Pred_90" for the 2008–2014 period seems to be caused by various reasons: (i) the gradual slowdown of human capital accumulation, (ii) decreasing investment rate, particularly after 2005, (iii) the stagnation of working-age population share after 2000, and (iv) the sudden stagnation of productivity after 2010, which can be confirmed by table 6.1.

Comparing the above patterns of predictions across Pred_70, Pred_80, and Pred_90, we learn that the prediction performance of the LTGM would be good when the economy grows in the stabilized environments, but the LTGM tends to underpredict when the parameters of investment rate, working-age population share, and labor force participation rate are actively changing. The prediction performance of the conventional calibration method (assuming constant values for key parameters) depends on the stage of development. The model with the conventional calibration method works very well for Korea when the Korean economy entered into the stable stage after 1990, while it performs poorly for the early catchup periods of the 1970s and 1980s. This illustrates that the application of the conventional calibration of the neoclassical growth model should be done with more care, the farther the economy is from the steady state.

4.4 Calibration 2: Time-Varying Parameter Embedded Simulation Approach

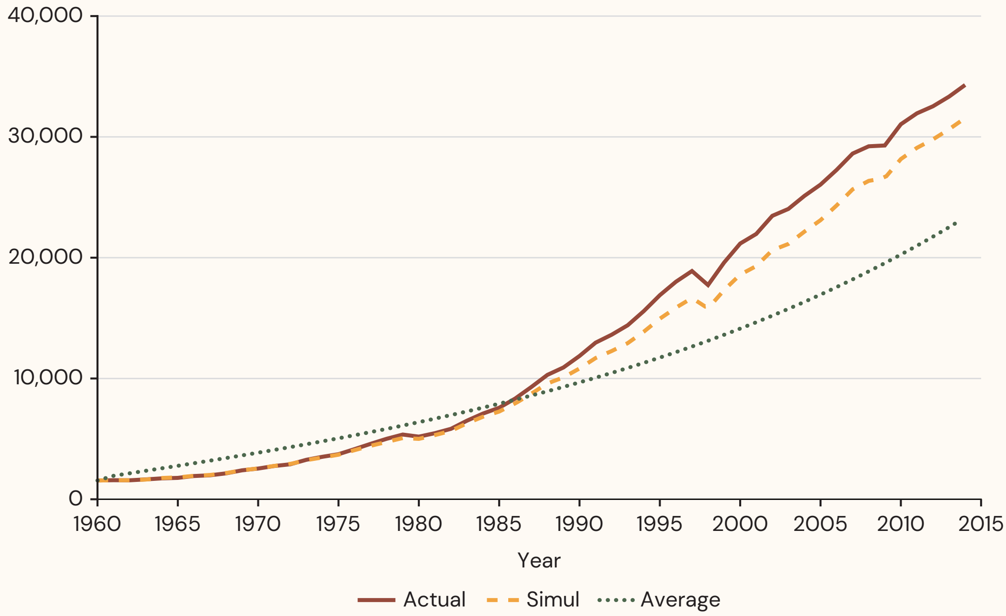
Another way of using the LTGM is to evaluate the expected changes of income growth in response to the different parameters of growth. For this exercise, we categorize the six parameters of calibration of the LTGM in the following manner. The rates of productivity growth and human capital growth are considered as the determinants of the steady-state growth. We call these two growth rates "fundamental growth parameters." The changes of the rest of the variables are related to "transitional growth." The changes of working-age population share, labor force participation rate, and population growth rate affect the growth via the demographic changes in labor market, hence we call the growth rates of these variables as "demography parameters." The change of investment rate affects growth via the capital accumulation process, and we call this an "investment parameter."

From this perspective, we can use the LTGM in order to evaluate the roles of different kinds of growth sources as follows. First, we simulate Korea's GDP per capita from the neoclassical growth model in section 2 by calibrating the six parameters varying over time as in the data, and consider this as the benchmark simulation. We label this version of simulation as "Simul." Second, we simulate by fixing all six policy parameters by their time-invariant long-run averages, i.e., by the 1960–2014 period annual average growth rates of productivity, human capital, population, and by the 1960–2014 period average values of investment rate, working-age population rate, and labor force participation rate. We label this version of simulation as "Average," which will capture the long-run growth effects in the sense that this simulation does not allow the time-varying patterns of the growth parameters. For this "Average" simulation, the six parameters are set by $g_A = 1.94\%$, $g_h = 1.5\%$, $g_N = 1.3\%$, $S_{W,0} = 0.65$, $S_{E,0} = 0.61$, and $\gamma_0 = 0.32$.

Figure 6.3 compares these two sets of simulations with the actual data. The full simulation, "Simul", captures the growth path of the actual real GDP per capita very well. The gap between the actual data and the "Simul" is due to the differences in the capital accumulation between the measured capital stock in PWT 9.0 data ("rkna" variable) that reflects the heterogeneous composition of capital goods and the simulated capital stock, which is constructed as in the law of motion equation (4) of the model, which does not differentiate the different types of capital.[11] Thus, the gap between the "Actual" and the "Simul" represents the compositional changes of heterogeneous types of capital assets over time in the process of Korean economic growth. It is interesting to notice that there is virtually no gap until the mid-1980s and the gap

[11] See Feenstra, Inklaar, and Timmer (2015) and User Guide of PWT 9.0 for more detailed discussion about the capital construction of the PWT 9.0 data.

Figure 6.3: Comparison of Predictions from Fully Time-Varying and Average Constant Simulations



Note: (1) Each line represents the actual or the predicted path of GDP per capita using different calibration methods. (2) "Actual" Actual GDP per capita, "Simul" Predicted GDP per capita calibrating at fully time-varying parameters, and "Average" Predicted GDP per capita calibrating at constant parameters of average values during the sample period.
Source: WDI and PWT 9.0

started to emerge only after 1985 and gradually widened afterward. This implies that the compositional changes in aggregate capital seems to matter only after the mid-1980s.

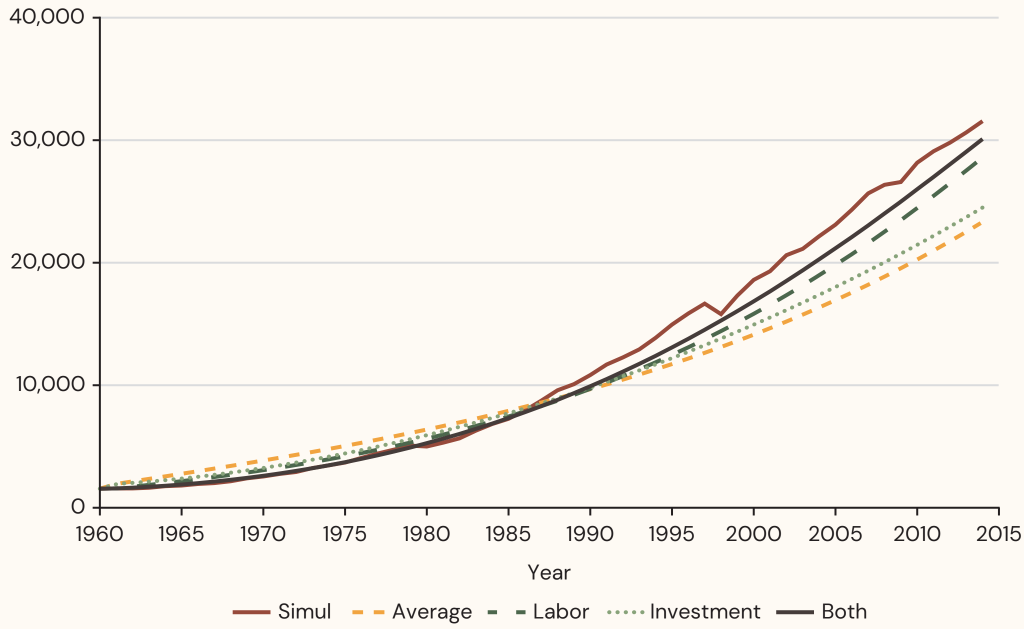
The "Average" represents mainly the long-run average growth effect holding the labor market demography and investment rates fixed. Therefore, the difference between "Average" and "Simul" reflects the contribution of the promotion of transitional growth policies such as changes in investment rate, working-age population, labor force participation, and population growth. This effect seems to be substantial, so that the promotion of transitional growth policies did matter for Korea's growth.

We can further decompose the time-varying transitional growth policy effects between the effects only from labor demography changes and the effects only from changes in the investment rate.[12] The simulations labeled as "Demography" and "Investment" in figure 6.4 represent such effects, respectively. "Both" captures the combined effect. It is interesting to notice that using the nonlinear trends of labor market demography and investment parameters, the model (simulation "Both") can fit the data very well, even though we fix the "fundamental growth parameters" of human capital growth rate and productivity growth rate. In this sense, the LTGM can be a promising tool to predict what would happen in response to the changes of labor market and investment policies and environments, with the appropriate selection of the long-run growth rates of productivity and human capital.

The good fit of the model simulation to Korean economic growth by allowing the time-varying labor market demography and investment parameters does not imply that the main engine of Korea's growth is the transitional growth sources. Such fitting performance is based on the productivity and human capital

[12] Here, we use the quartic-polynomial-fit trend for each time-varying variable rather than using the actual data.

Figure 6.4: Labor and Investment Policy Effects

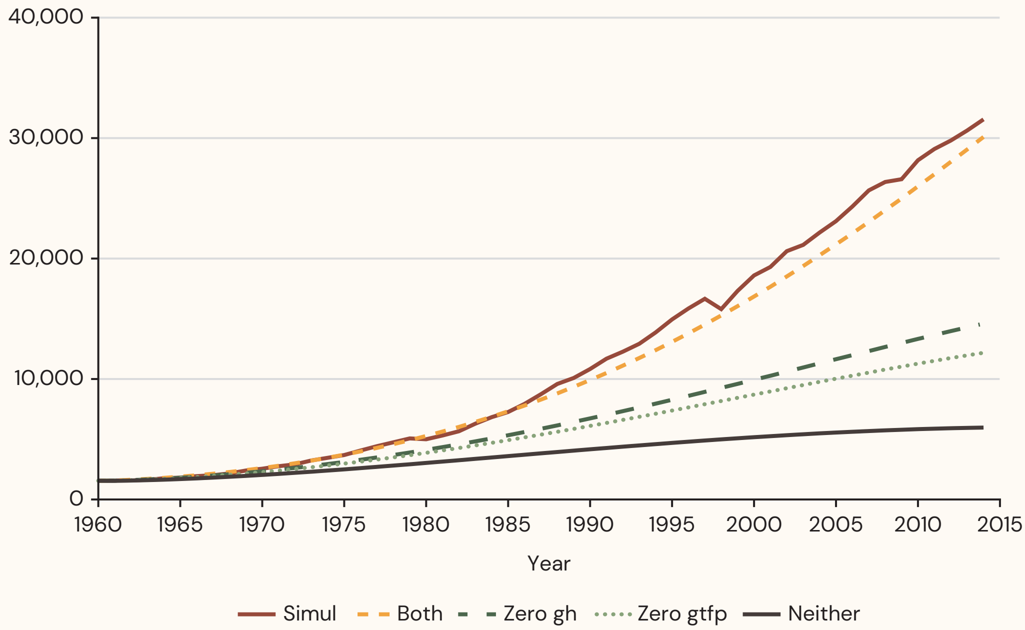


Note: (1) Each line represents the actual or the predicted path of GDP per capita using different calibration methods. (2) "Simul" Predicted GDP per capita calibrating at fully time-varying parameters, "Average" Predicted GDP per capita calibrating at constant parameters of average values during the sample period, "Demography" Predicted GDP per capita allowing time-variation only for the labor market demography parameters, "Investment" Predicted GDP per capita allowing time-variation only for the investment rate parameter, and "Both" Predicted GDP per capita allowing time-variation for both labor market demography and investment rate parameters.
Source: WDI and PWT 9.0

growth rates of 1.9% and 1.5% every year in the background. To evaluate the role of such fundamental growth parameters, we simulate the model at the time-varying labor market demography and investment parameters, but turn off the productivity growth, human capital growth, or both to zero. The simulated paths of the real GDP per capita of these simulations, are labeled as "No g_h," "No g_A," and "Neither," respectively, in figure 6.5. This shows that Korea's growth performance would have been *unimpressive*, although the investment and labor market demographic factors had been actively promoted as in Korea, if they had been the only sources of growth.

In the year of 2014, Korea's real GDP per capita is US$34,300 in 2011 US dollars using national prices and US$35,103 using PPP adjusted prices according to the PWT 9 data. The Korea's PPP-adjusted real GDP per capita in 2014 is slightly lower than that of Japan (US$35,358) and a little higher than that of Spain (US$33,864) in the same year. In 1960, Korea's PPP-adjusted real GDP per capita was US$1,175 which was lower than those of Kenya, Tanzania, Bangladesh and Haiti, while those of Japan and Spain were US$5,351 and US$5,741, respectively. Without human capital growth, Korea's 2014 real income level would have been US$14,597 (close to the level of Brazil in 2014). Without productivity growth, Korea's 2014 real income level would have been US$12,178 (close to the level of South Africa in 2014). With neither productivity and human capital growth, Korea's 2014 real income level would have been US$5,970 (close to level of Bolivia in 2014). The above comparison clearly illustrates that the main backbones of Korea's "miraculous growth," as is asserted by Lucas (1993), are the productivity growth and human capital accumulation, although the active promotion of labor market demography and investment played a non-negligible role as well. That is, Korea's growth experience shows that the most critical factors for successful and sustainable growth are the productivity and human capital growth, i.e., the fundamental sources of long-run growth rather than the sources of transitional growth, which confirms the key insights of the neoclassical growth theory.

Figure 6.5: Long-Run Growth Effects



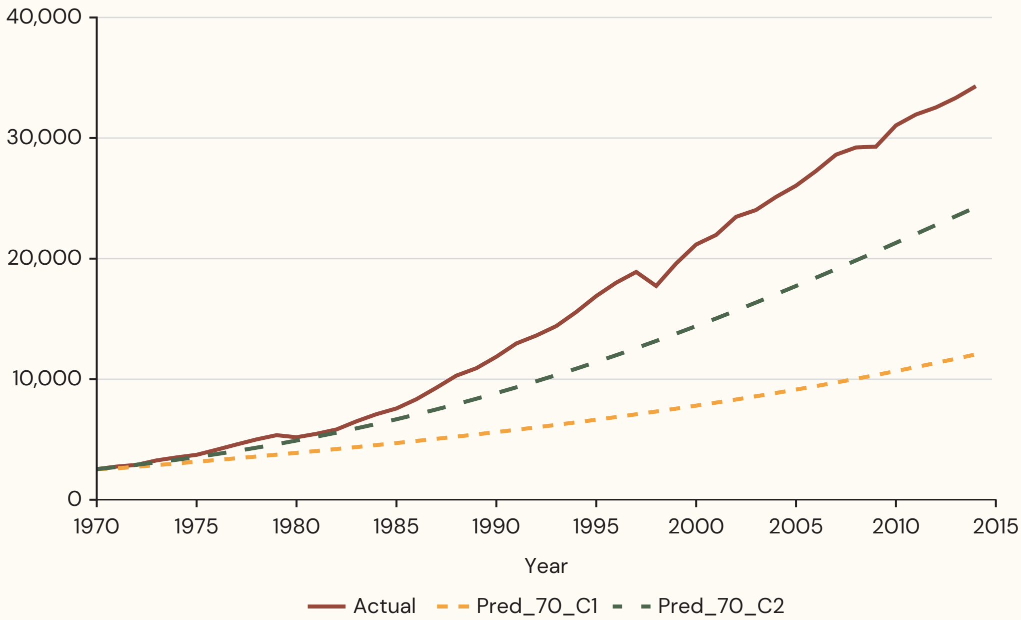
Note: (1) Each line represents the actual or the predicted path of GDP per capita using different calibration methods. (2) "Simul" Predicted GDP per capita calibrating at fully time-varying parameters, "Both" Predicted GDP per capita calibrating at constant fundamental parameters of human capital and labor-augmenting productivity growth, "No g_h" Predicted GDP per capita with no human capital growth, "No g_A" Predicted GDP per capita with no labor-augmenting productivity growth, and "Neither" Predicted GDP per capita with neither human capital nor labor-augmenting productivity growth.
Source: WDI and PWT 9.0

The above counterfactual analysis of varying growth sources quantitatively identifies the roles of transitional versus long-run growth. It suggests that the major sources of sustainable and fast growth for Korea were the productivity and human capital growth, although the time-varying promotion of investment and labor force participation also played significant roles as well. It is worth mentioning that the two types of growth (transitional and fundamental growth) are not independent from each other, so that the above counterfactual analysis results do not sum up in an accounting way. In fact, this is the key nature of the neoclassical model and the difference from the simple growth accounting analysis in section 3. For example, the gap between the simulated GDP per capita in 2014 from "Simul" with full variation of parameters and that of "Neither" in figure 6.5 (which captures the whole effect of productivity and human capital growth) is larger than the simulated income level in 2014 from "Average" in figure 6.3 (which captures the growth from the constant rates of productivity and human capital growth at average values). This can happen because the magnitude of the diminishing returns to capital investment changes over the capital accumulation process, and it interacts with the fundamental growth parameters. During the initial stage of development when the capital stock is not abundant relative to output (i.e., capital-output ratio is low), the magnitude of diminishing return is not big, hence the size of the induced extra capital accumulation from productivity growth would not be large. Such an interaction effect between capital and productivity becomes larger as the capital-output ratio increases. From the growth accounting analysis in table 6.1, we discussed the sequential feature of Korea's growth such that productivity growth was accelerated after 1980 and became the major engine of Korea's growth. This is exactly the period when the speed of capital deepening started to slow down so that the rapid 2.2% to 3.7% growth in productivity per annum during the 1980–2010 period, higher than the sample period average productivity growth rate at 1.9%, played an important role of overcoming the diminishing returns to capital investment. This seems to be a critical reason behind the sustained growth of Korea for six decades.

The above calibrations use the long-run average rates of growth of human capital and productivity for the entire period. The policy makers in 1970 might not have the precise estimates for the six-decade long-run growth of productivity and human capital growth. For them, the best estimates would have been formed by the adaptive expectation using the average values during the 1960–1970 period, which we used in calibration 1 in the previous subsection. There we found that the model simulation "Pred_70" predicts much lower than the actual data, and the discrepancy emerges very shortly after the beginning of simulation. Then, from the viewpoint of the 1970 policy makers, it is an interesting exercise to predict what Korea's growth path would look like if Korea had implemented the growth policies of increasing the transitional growth parameters for investment and labor force, maintaining the 1960–1970 growth rates of productivity and human capital ($g_A = 0.8\%$, $g_h = 2.2\%$). Learning from the above counterfactual analysis that allowing the time-varying transitional growth parameters improves the prediction performance of the model from the above analysis, we may evaluate the effects of the time-varying promotion of the transitional growth parameters at the time of 1970, when policy makers would use the estimates for the productivity and human capital growth from the past data from the 1960–1970 period.

Figure 6.6 compares the predicted path of such simulation "Pred_70_C2" with that of conventional calibration "Pred_70_C1" (same as the "Pred_70" in figure 6.2). The gap between "Pred_70_C1" and "Pred_70_C2" measures the expected effect of increasing the transitional growth parameters for investment and labor force for the 1970 policy makers. Figure 6.6 suggests that the effect of such a transitional growth policy is substantial. Furthermore, the model fit for the first decade or so after the prediction time is very close to the data, which shows that the simple neoclassical growth model can be a good device for the policy makers for the decade-period growth prediction. That is, the LTGM can be used for the policy makers of developing countries in assessing the short- or medium-term growth effects from the promotion of investment and labor force participation, based on the above analysis of Korea's growth experience. A caveat here is that the 1960–1970 period human capital growth rate of 2.2% is higher than the entire sample period average of 1.5%.

Figure 6.6: Role of Time-Varying Transitional Growth for Policy Prescription in 1970



Note: "Actual": Actual GDP per capita, "Pred_70_C1" Predicted GDP per capita calibrating both transitional and fundamental parameters at constant values from the 1960–1970 data, and "Pred_70_C2" Predicted GDP per capita calibrating both fundamental parameters at constant values from the 1960–1970 data but allowing time-varying values for transitional growth parameters.
Source: WDI and PWT 9.0

At the same time, however, we should emphasize that such a growth effect from the promotion of transitional growth parameters is conditional on sustaining the productivity and human capital growth at fairly high rates, 0.8% and 2.2%, respectively. We already showed in figure 6.5 that turning off the engines of fundamental growth could have made Korea's growth performance negligible. So, it would be an error for the 1970 policy makers to expect the substantial growth only from the investment and labor force participation promotion. Furthermore, Korea's stellar performance of growth was not simply based on maintaining the 1960–1970 growth rates of productivity and human capital. The "Actual" GDP per capita in 2014 (US$34,300) still exceeds the "Pred_70_C2" GDP per capita in 2014 (US$24,265) in a big order of magnitude by US$10,000, which is attributed to the *acceleration of productivity growth*. Thus, we may conclude that the proper advice for the 1970 policy makers (i.e., the policy makers of developing countries where their GDP per capita levels are close to that of Korea in 1970) would be to bolster the fundamental growth parameters, particularly, the productivity growth, together with the expansion of investment and labor force.

5. Conclusion

Korea's remarkable growth experience itself may inspire the developing world because Korea started such development from the comprehensive set of adverse conditions (colonization, massive civil war, corruption, lack of physical and human resources, political instability and incessant ideological conflicts, etc.) that are often mentioned as critical barriers to development among the current developing countries. However, without clarifying and quantifying what are actually behind such a growth process, Korea's development experience would be useless for other developing countries. This chapter attempted to provide such a quantitative analysis to shed light on the underlying mechanisms of Korea's growth from the macroeconomic perspective using the framework of the neoclassical growth model, which is the workhorse of the World Bank's LTGM project.

From the decomposition analysis, we found that the most important source of Korean economic growth for the 1960–2014 period was productivity growth, contributing to the growth of GDP per capita by 1.9% each year on average for 55 years. The second largest contributing component was human capital accumulation (1.5% each year), and the capital deepening effect was the third (1.3% each year). The labor market demographic compositional changes such as the increases in working-age population share and labor force participation rate also contributed to the GDP per capita growth substantially by 1.0% each year. These results show that the underlying sources of Korea's growth were fairly balanced among different growth components, while productivity growth was the main driving force behind the scene. Furthermore, the major contributing components to growth evolved over time from labor demography and human capital in the 1960s to capital deepening in the 1970s to productivity growth for the following three decades. In particular, the accelerated productivity growth after 1980 was a critical reason for the sustainable growth for Korea because such productivity growth contributed to overcoming the force of diminishing returns to capital investment which has a tendency to slow down the growth.

This picture is different from what many of the first generation of Korea's development policy makers used to have in mind, who would consider the human and physical capital accumulation as the main engines of Korean growth. It was, in fact, the case in the 1960s and 1970s. In the 1960s, human capital growth, based on rapid expansion of universal education at primary and secondary levels of schooling, was the main engine of Korea's growth. In the 1970s, capital deepening due to the increasing investment rate promoted by export-oriented industrial policies indeed was the main engine of Korea's growth. However, what bolstered Korea's sustaining growth throughout, particularly for the 1980–2010 period, was the productivity growth, which has been rarely emphasized in most discourses about Korean economic growth.

We characterized the important features of the LTGM as a simulated prediction or policy prescription tool, by calibrating the model to Korea's growth experience ex post in various ways. We found that conventional calibration (assuming constant growth parameters) of the neoclassical growth model poorly fits Korea's growth path when Korean economy was in early transition periods. However, for the period after 1990 (when we consider the Korean economy started to enter the stability period), even the conventional calibration of the model predicts the actual growth fairly well. Even for the fast transition period before 1990, we found that the model fits Korea's growth path very well by allowing *time-varying* transitional growth parameters (labor market demographic composition changes and investment rate) with maintaining fundamental growth parameters (productivity and human capital growth rates) at constant values. Such goodness of fit of the neoclassical growth model is a (pleasant) surprise because the model is not built to fit the data in a reduced-form way. This tells us that the LTGM can provide a useful tool for policy guidance for the policy makers in designing their growth policies.

Finally, our counterfactual calibration analysis suggests that the fundamental importance of productivity and human capital for sustainable growth is confirmed by Korea's growth experience, despite the significant contribution of the promotion of investment and labor force expansion. This is the ultimate lesson from Korea's growth experience, which should be delivered to the policy makers of the developing countries that aim to achieve such a miraculous transformation. This chapter leaves the studies about more concrete micro mechanisms and policy measures behind for future research. The main contribution of this chapter is to point where the priority of the development policy and strategy should be directed to, and to quantify its effects on growth, based on Korea's growth experience.

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Chapter 7

Long-Term Growth Scenarios for Bangladesh[1]

Rishabh Sinha[2]

Abstract

Bangladesh has achieved robust economic growth for the last 10 years, with real gross domestic product (GDP) growing by more than 6 percent on average each year. This chapter investigates whether the country will be able to maintain such high levels of growth going forward. The chapter uses the Long Term Growth Model (LTGM), which is calibrated to the Bangladesh economy to analyze various growth scenarios. The main finding of the chapter is that it is crucial for the country to focus on reforms to raise TFP growth in order to sustain the high real GDP growth rate seen in the recent past. The country will fail to achieve high growth in the absence of strong TFP growth despite meeting the levels of investment as outlined in the 7th Five Year Plan. The model is also used to gain insights on government debt sustainability given different growth scenarios. The analysis highlights the significance of meeting revenue targets in maintaining sustainability, considering the planned expansion in expenditures.

JEL Classification: O40, O53, J24.
Keywords: Long-term growth, Bangladesh, TFP growth, labor productivity.

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[2] Rishabh Sinha, World Bank. Email: rishabhsinha@worldbank.org. I am grateful to Afroza Alam, Hans Beck, Simon Davies, Ralph Van Doorn, Zahid Hussain, Sheikh Tanjeb Islam, Frederico Sander, Muhammad Waheed, and workshop participants from the Ministry of Finance, Bangladesh and the Bangladesh Bank for many useful insights and suggestions. The World Bank's Long-Term Growth Model (as in chapter 1) has been used extensively for the quantitative analysis presented in the paper. The findings, interpretations, and conclusions expressed in this paper are entirely those of the author. They do not necessarily represent the views of the International Bank for Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.

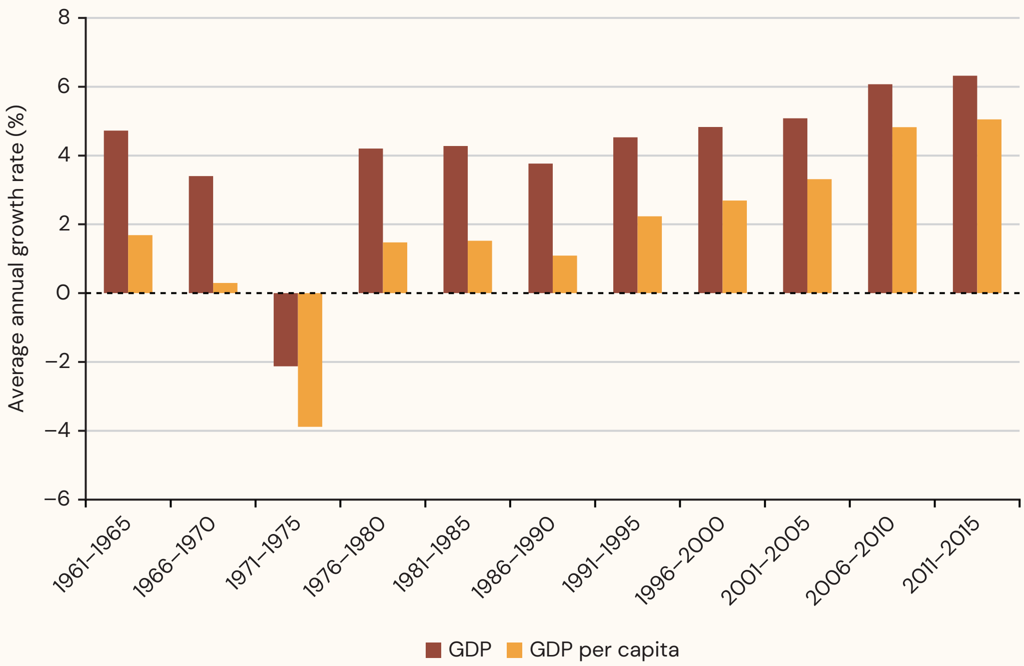
1. Introduction

Bangladesh has seen robust economic growth during the last decade with real GDP growing by more than 6 percent on average every year during 2006–2015 (Figure 7.1). Additionally, the economy has seen a long-term acceleration in growth since the late 1970s when the real GDP was growing by just over 4 percent annually. The acceleration in real GDP growth has also translated to an acceleration in real GDP per capita growth, as the gap between real GDP growth and population growth has been widening over time.[3] Beginning from US$352 in 1980, real GDP per capita (measured in 2010 US dollars) crossed US$700 in 2008 and is on mark to cross US$1,000 next year. The sustained economic growth during the last few decades has helped the country graduate from a low-income country to a lower-middle-income country as classified by the World Bank (World Bank 2015).

To better understand the sustained growth achieved by the country, it is useful to explore how some of the key growth drivers have evolved during this period. Capital accumulation has been a key driver of economic growth for many countries, and Bangladesh is no exception to this phenomenon. Bangladesh has realized a continued rise in the investment share of GDP during the last 35 years. The investment share of GDP has almost doubled from 14.4 percent of GDP in 1980 to 28.9 percent of GDP in 2015 (Figure 7.2). Most of this increase has been driven by gains in private investment. With respect to its Asian neighbors, the country currently has a higher investment rate compared to Pakistan and Nepal but lags behind China and India.

The country has witnessed many changes in the labor market that have been important for growth. The demographic transition has led to a decline in the dependency ratio with the share of the working-age population rising continuously over time. Starting from 52 percent of the total population in 1980, the working age population share grew by more than 13 percentage points in the last 35 years (Figure 7.3). The growth

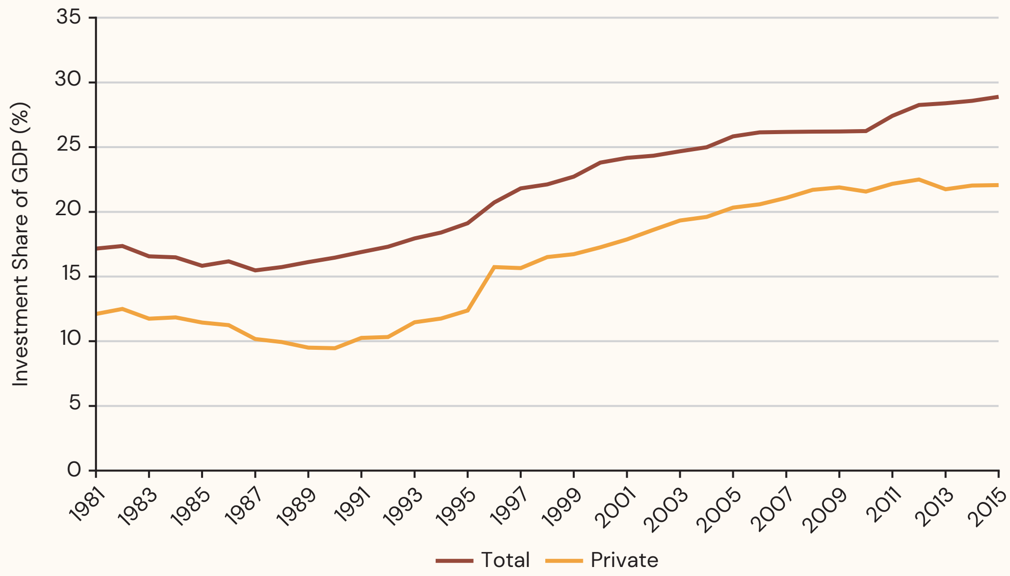
Figure 7.1: **GDP and GDP per Capita Average Annual Growth Rate**



Source: World Development Indicators.

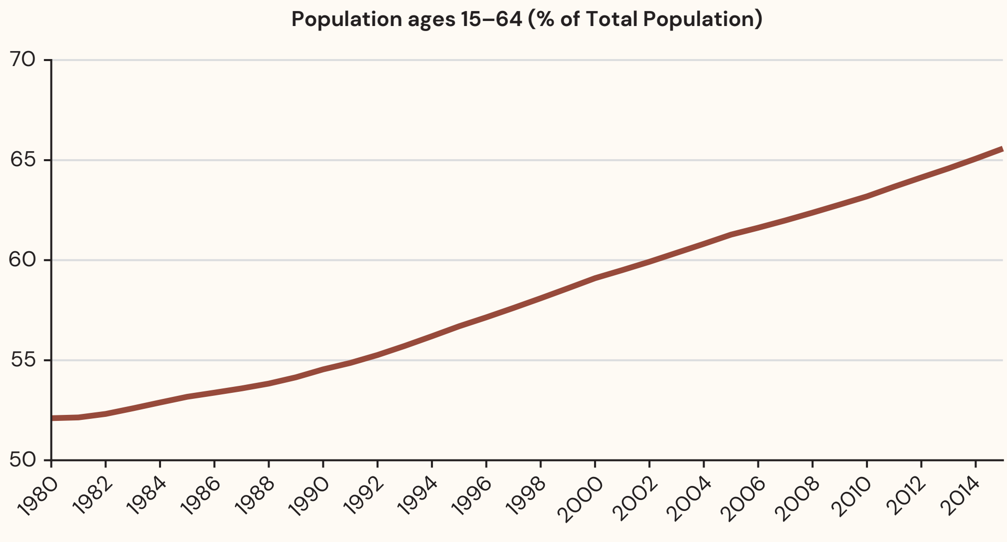
[3] Real GDP per capita saw negative growth during 1960–1980 but has been rising ever since.

Figure 7.2: Total and Private Investment Share of GDP



Source: World Development Indicators.

Figure 7.3: Working Age Population



Source: World Development Indicators.

received further tailwind from increasing participation rates. The aggregate participation rate rose from approximately 45 percent in the mid-1970s to over 60 percent in the 2010s, largely due to the massive jump in the female labor force participation rate that grew from a low base of 12 percent in 1989 to 30 percent in 2013. What has been most encouraging is that not only the quantity but also the quality of labor resources has been rising over time. The Penn World Table (PWT) human capital index for Bangladesh has grown by more than 1.5 percent per year on average during 1990–2010.

Apart from growth in underlying factors of production— capital and labor—economic growth can also be derived from advances in technology or through an efficient use of existing resources. The growth in the productivity of resources, or Total Factor Productivity (TFP), has been an important driver of growth for many countries.[4] The TFP growth rate for Bangladesh during 2001–2011 has just been above zero, implying that the strong growth seen during the period was not aided by either technology adoption or through efficiency in resource allocation. On the other hand, India and China, who also realized healthy economic growth during the same period, were aided significantly by productivity, with TFP growing by 1.3 percent and 2.9 percent on average each year, respectively. However, the uptick in TFP growth since the later 2000s is encouraging, and continued reforms can help the country move into an era of sustained positive TFP growth.

The important question going into the future is whether the country can continue on its path of accelerating growth or not. The goal is to identify areas that need reform and quantify the relative merit of alternative growth strategies. Such an analysis will help isolate factors that are most likely to be the key drivers of growth. The analysis uses the standard Long Term Growth Model (LTGM)—as in chapter 1 of this volume—to answer these questions. The model uses investment, savings, and productivity as building blocks and ties these variables to economic growth. The model also includes labor market forces that are important in driving growth, together with an external sector through which additional investment can be sourced. An important finding from the growth equation obtained after solving the model shows that investment becomes less effective in generating growth with an increase in the capital-to-output ratio. This implies that the same level of the investment share of output will generate lower growth if capital in the economy is growing faster than output. Hence, an investment-led growth strategy in absence of reforms that focus on growth of productivity, human capital, and participation will eventually run out of steam.

The model is calibrated for Bangladesh by matching some of the standard moments in the growth literature. An appealing feature of the model is that it is fairly parsimonious with regards to the parameters. Nonetheless, robustness checks are performed around the parameter values used in the benchmark exercises. The calibrated model is then used to perform several quantitative exercises that feature different scenarios on how the drivers of growth evolve over time.

The main finding of the analysis is that for Bangladesh to sustain a high real GDP growth rate, it is essential that the country focuses on reforms that drive TFP growth. An investment-led strategy that boosts the investment share to 35 percent by 2020, coupled with improvements in the efficiency of public capital, will deliver a GDP growth of 5 percent for the next decade. However, maintaining such a level of investment will deliver lower than 5 percent GDP growth beyond 2025 in absence of TFP growth, as a high capital-to-output ratio will make investment less and less productive in generating growth. Alternatively, a sustained high GDP growth path in absence of TFP growth will require massive investments that exceed the levels targeted by the government. More alarmingly, the required investments will soon reach levels that are unrealistic to attain.

Finally, the model can also be used to infer what the implied growth paths spell for the sustainability of the government debt position. The country has a low government debt to GDP ratio which stood at 34 percent at the end of 2015. The analysis finds that the government debt situation is sensitive to government operations and that meeting tax revenue targets is essential to keep the government debt to GDP ratio in check. The government debt sustainability will face additional risk if the government overshoots its expenditure without making much progress on the revenue front.

[4] The estimated TFP growth series is usually volatile and is also sensitive to the method of estimation. TFP is estimated as a residual after accounting for all factors of production, and the estimates across studies are bound to differ if they employ a different production function or measure factors of production differently. For example, estimates of TFP will differ for a study that accounts for human capital based on schooling compared to a study that does not account for human capital gains that stem from schooling.

2. The LTGM— A Simple Growth Model

The LTGM is used to quantitatively analyze the growth prospects of Bangladesh. The LTGM is a simple extension of the Solow (1956)–Swan (1956) model and is presented in discrete time. The model is essentially the same as that in chapter 1, but is presented here for completeness.

The economy consists of a single sector that produces a final good using capital and labor resources. The production is carried out using a standard Cobb-Douglas production technology given by

$$Y_t = A_t K_t^{1-\beta}(h_t L_t)^{\beta} \tag{1}$$

where K_t is the aggregate capital stock, h_t is the human capital per worker and L_t is the total number of workers present in the economy. A_t denotes the common total factor productivity term that captures the productivity of both factors of production. The time invariant parameter β is the aggregate labor share of income. As seen from the production function, output growth can be achieved through three channels—accumulation of capital resources, accumulation of labor resources, and productivity growth.

Accumulation of physical capital is realized via investment. The next period capital stock K_{t+1} equals the undepreciated portion of the previous period's capital stock K_t together with the investment made in the previous period I_t. The capital accumulation equation is given by

$$K_{t+1} = (1-\delta)K_t + I_t \tag{2}$$

where δ represents the per period depreciation rate of physical capital.

The *effective labor* used in production is the product of human capital per worker h_t and the total number of workers N_t present in the economy. Human capital per worker determines the productivity of labor resources and is assumed to increase with increases in years of schooling. The total number of workers employed in production depends on population as well as the labor market. The total number of workers employed can be written as

$$L_t = \rho_t \omega_t N_t \tag{3}$$

where ρ_t is the participation rate, ω_t is the working-age population to population ratio, and N_t is the total population. Effective labor in the economy can grow as a result of either an increase in human capital per worker or through an increase in the total number of workers. The total number of workers, in turn, can increase via increases in participation rate, working-age population to population ratio, or population.

Equation (1) can be used to express the output in per capita terms. Dividing both sides of the equation by total population yields

$$y_t^{pc} = \rho_t \omega_t A_t k_t^{1-\beta} h_t^{\beta} \tag{4}$$

where y_t^{pc} is the output per capita and K_t is the capital per worker. Equation (4) can be used to calculate growth of output per capita from t to $t+1$

$$\frac{y_{t+1}^{pc}}{y_t^{pc}} = \left(\frac{\rho_{t+1}}{\rho_t}\right)\left(\frac{\omega_{t+1}}{\omega_t}\right)\left(\frac{A_{t+1}}{A_t}\right)\left(\frac{k_{t+1}}{k_t}\right)^{1-\beta}\left(\frac{h_{t+1}}{h_t}\right)^{\beta} \tag{5}$$

which can be rewritten in terms of various growth rates from t to $t+1$ as follows

$$1+g_{y,t+1}^{pc} = (1+g_{\rho,t+1})(1+g_{\omega,t+1})(1+g_{A,t+1})(1+g_{k,t+1})^{1-\beta}(1+g_{h,t+1})^{\beta} \tag{6}$$

where growth rate of a variable x from t to $t+1$ is denoted by $g_{x,t+1}$.

In order to make analytical progress, the relationship between investment and capital per worker needs to be established. The capital accumulation equation (2) can be written as

$$\left(\frac{K_{t+1}}{L_{t+1}}\right)\left(\frac{L_{t+1}}{L_t}\right)=(1-\delta)\left(\frac{K_t}{L_t}\right)+\frac{I_t}{L_t}$$

Dividing both sides of the above equation by K_t writing in per worker terms and growth rates gives

$$(1+g_{k,t+1})(1+g_{N,t+1})(1+g_{\rho,t+1})(1+g_{\omega,t+1})=(1-\delta)+\frac{\left(\frac{I_t}{Y_t}\right)}{\left(\frac{K_t}{Y_t}\right)}$$

Rearranging the above equation so as to isolate the growth rate of capital per worker $g_{k,t+1}$ yields Equation (7) below

$$(1+g_{k,t+1})=\frac{\left((1-\delta)+\frac{\left(\frac{I_t}{Y_t}\right)}{\left(\frac{K_t}{Y_t}\right)}\right)}{(1+g_{N,t+1})(1+g_{\rho,t+1})(1+g_{\omega,t+1})} \qquad (7)$$

Equations (6) and (7) characterize the growth of the economy and are used for quantitative analysis. However, before embarking on the quantitative exercises, it is important to understand what drives growth in this model.

2.1 Drivers of growth

A log-linear approximation can be used to simplify the growth equations. Specifically, equation (7) is substituted in equation (6) and the approximation returns the following relationship

$$g^{pc}_{y,t+1}\approx g_{A,t+1}+\beta(g_{\rho,t+1}+g_{\omega,t+1}+g_{h,t+1})+(1-\beta)\left[\frac{\frac{I_t}{Y_t}}{\frac{K_t}{Y_t}}-\delta-g_{N,t+1}\right] \qquad (8)$$

The above equation offers many insights regarding the drivers of growth. First, the TFP growth g_A has the largest direct effect on growth where a 1 percentage point increase in TFP leads to a 1 percentage point increase in the growth rate of output per capita. Second, the production function parameter β plays an important role in determining the relative importance of capital and labor growth in driving aggregate growth. The larger the labor share of income, the more responsive is the output growth to increases in participation rate, working-age population to population ratio, and human capital per worker. Conversely, the larger the labor share of income, the lower the effect of capital accumulation in generating growth. Finally, it is important to note that keeping all else constant, the same level of the investment share of output can lead to different output growth rates depending on the level of capital-to-output ratio $\left(\frac{K}{Y}\right)$ of the economy. Investment becomes less effective as the capital-to-output ratio rises in the economy. This implies that the same level of the investment share of output will generate lower growth if capital in the economy grows faster than the output. Hence, an investment-led growth strategy in absence of reforms that focus on growth of productivity, human capital, and participation will eventually run out of steam.

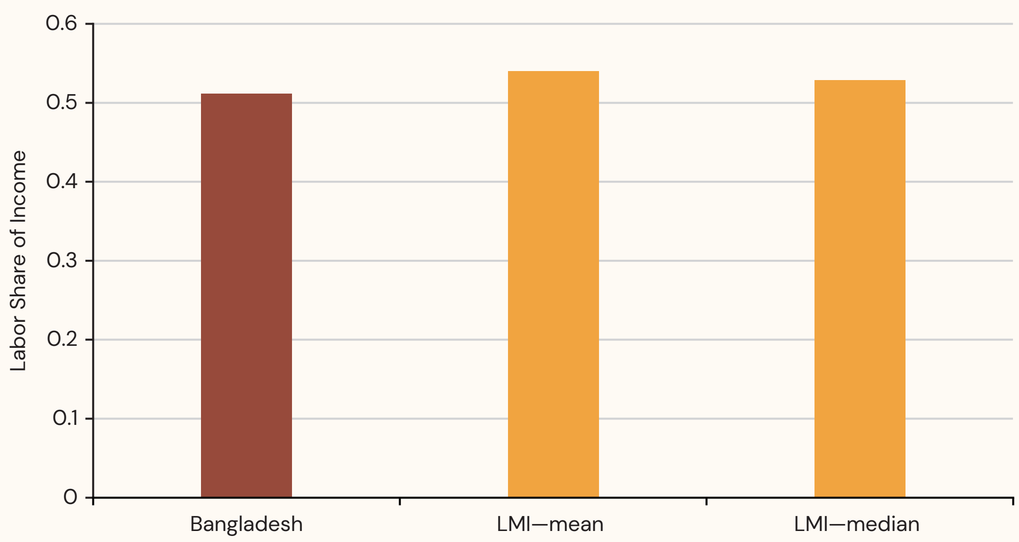
In the next section, I begin with the quantitative analysis and examine various growth scenarios for the country. The first step of the analysis requires the calibration of the model to the Bangladesh economy. Following calibration of the model, the long-term growth scenarios for the country are considered by asking two related questions. First, how much growth can be achieved under various reasonable paths of growth drivers and second, what time paths of growth drivers, in particular investment, are essential to realize a given growth path.

3. Quantitative Analysis

Each period of the model corresponds to a year, which implies that all growth rates are annual in nature. A desirable feature of the model is that it is parsimonious with regards to parameters. There are only three parameters that need calibration— labor share of income β, depreciation rate δ, and initial capital-to-output ratio $\frac{K_0}{Y_0}$.

- **Labor share of income: β = 0.51** The Penn World Table 8.1 does not contain the labor share data for the case of Bangladesh. An alternative source that provides guidance for this parameter is the Global Trade Analysis Project (GTAP). The GTAP database contains information that can be used to calculate the aggregate labor share.[5] The most recent year for which data are available is 2011, which is used to arrive at the labor share of 0.51 for Bangladesh. Figure 7.4 below compares the labor share of income of Bangladesh to the mean/median labor shares of lower-middle-income countries obtained from PWT 8.1 for the year 2011. The labor share of the country lies close to the mean/median of the lower-middle-income countries though somewhat lower. In the robustness exercises, I show how alternative values of β affect the results of the analysis.
- **Depreciation rate: δ = 0.032.** The annual depreciation rate of capital stock is sourced from the PWT 8.1. The PWT 8.1 classifies capital stock into six different categories with each category having a different rate of depreciation. A somewhat lower depreciation rate for Bangladesh is rooted in the fact that the country has a larger share of capital stock in assets that depreciate slowly, relative to assets that have a

Figure 7.4: Labor Share of Income



Source: PWT 8.1, GTAP.

[5] See Hertel, Tsigas, and Narayanan (2002) on details regarding the calculation of labor shares in the GTAP database.

much higher rate of depreciation such as computers, software, and so forth. The aggregate depreciation rate for the country is likely to inch upward as the capital mix shifts toward assets that have a higher depreciation rate. The robustness exercises discuss the sensitivity of findings to the choice of higher depreciation rates.

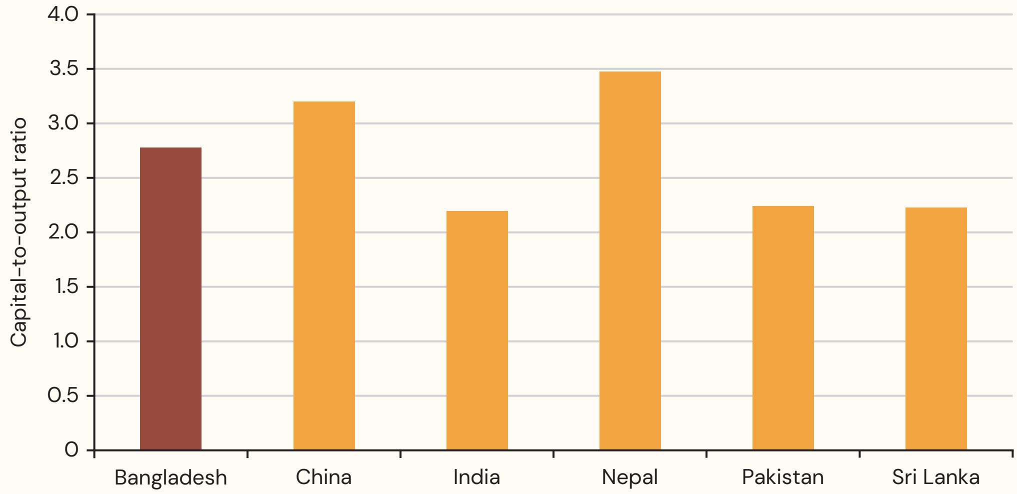
- **Initial capital-to-output ratio: $\frac{K_0}{Y_0} = 2.78$.** The initial capital-to-output ratio is calculated using the capital stock and GDP data from the PWT 8.1. The most recent year for which data are available from the PWT 8.1 is 2011 which is used to calculate the specified value of capital-to-output ratio. Figure 7.5 below compares the capital-to-output ratio of the country with some of its neighbors. The capital-to-output ratio of the country is lower compared to China, driven by the fact that China has made massive investments in capital stock over the last few decades. Though still in a range with other neighbors except Nepal, the capital-to-output ratio is somewhat higher for Bangladesh. As seen in equation (8), a higher value of capital-to-output ratio puts downward pressure on the growth impact from increasing investment.

3.1 Growth Consistent with Reasonable Time Paths of Growth Drivers

Having calibrated the model, I now move to analyze the long-term growth scenarios for the country. The first approach consists of choosing reasonable paths of drivers of growth and using the model to solve for the resulting growth paths. Specifically, I assume the following time paths:

- **Growth rate of human capital per worker: $g_h = 1.3\%$.** The historical trend in human capital index from the PWT 8.1 provides guidance regarding the reasonable path of human capital per worker going forward. The PWT 8.1 reports the index based on the Barro-Lee method that takes into account both the years of schooling as well as returns on education. The PWT 8.1 data are available for the period 1990–2010. After reaching a peak during the second half of the 1990s, the growth of human capital index has been on a downward trend (Figure 7.6). The average growth rate stood just below 1.4 percent during the period 2006–2010. It seems likely that the growth rate of human capital will continue its gradual decline with contributions from gains in primary education diminishing as it reaches absolute levels. As such, the human capital per worker growth rate is assumed to be 1.3 percent per annum going into the future.
- **Growth rate of TFP: $g_A = 0\%$.** A TFP index for the country is calculated using the data and methodology listed in PWT 8.1 and using the labor share of 0.51 obtained from the GTAP database. The growth rate

Figure 7.5: Capital-to-Output Ratio



Source: PWT 8.1.

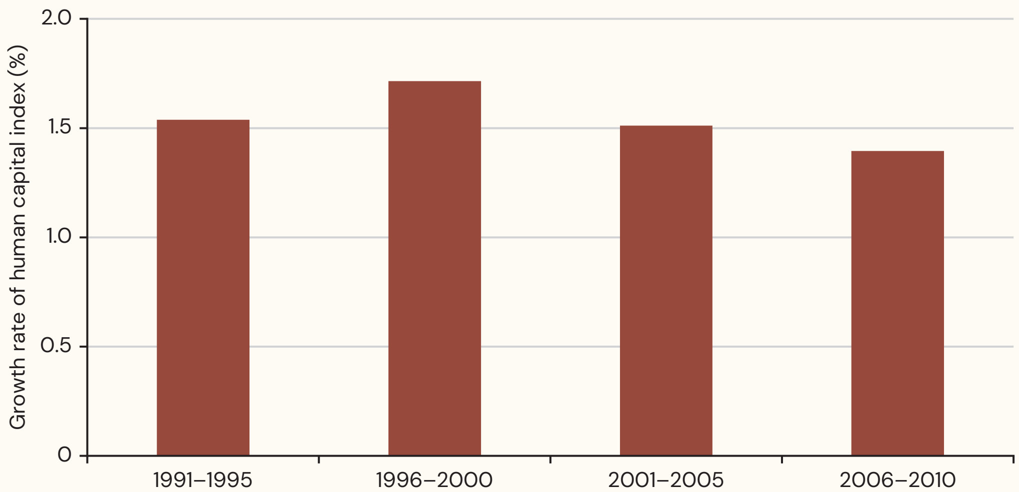
of TFP is generally volatile, and it is also true for the case of Bangladesh as seen in figure 7.7. The TFP was on an upward trend from the 1980s till it suddenly dropped in 2001. After remaining in the negative territory for another two years, the TFP growth started trending upwards again. The average growth rate of TFP during 1991–2011 has barely managed to remain in the positive territory. Given the volatile nature of TFP growth and the average recorded for the 1991–2011 period, it is assumed that the country will not experience any meaningful TFP growth in the long term.

- **Growth rate of population: g_N.** The population projections have been sourced from the World Bank's Human Development Network estimates. According to the Human Development Network, the annual population growth rate for the country will decline from the present 1.2 percent to 1.0 percent by 2021 and 0.7 percent by 2030.
- **Growth rate of working-age population to population ratio: g_w.** In addition to the population forecasts, the Human Development Network also provides projections for the working-age population of men and women separately (Figure 7.8). The projections indicate that the aggregate working-age population to population ratio in Bangladesh will continue to rise and reach almost 70 percent by the year 2030, a gain of 4 percentage points from the current levels.

There are two more time paths that are needed to run the growth simulations— investment share of GDP $\left(\frac{I_t}{Y_t}\right)$ and participation rate (ρ_t). Both these drivers of growth are expected to play a big role going forward and have been identified as such by the policy makers. For this reason, I consider different scenarios for their time paths that help in identifying their relative importance.

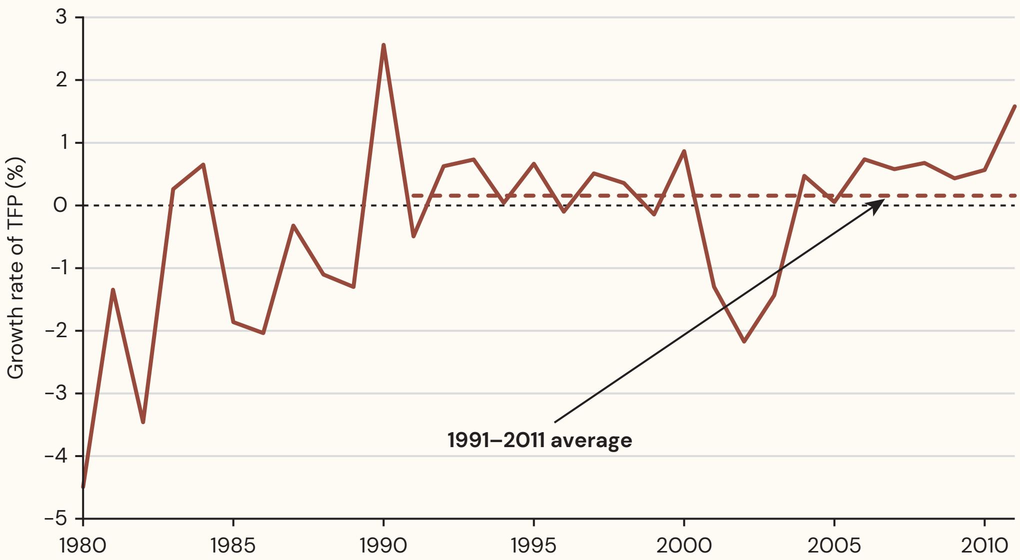
- **Investment share of GDP: $\left(\frac{I_t}{Y_t}\right)$.** Bangladesh has realized a continued increase in the investment share of GDP during the last 35 years. The investment share of GDP has almost doubled from 1980 to 2015, with most of the increases coming from private investment. Needless to say, capital accumulation has been an important driver of growth in the country. This point is illustrated in figure 7.9, which shows the average GDP per capita growth rate during 2011–2015 against the average investment share during the same period for more than 200 countries for which data are available from the World Development

Figure 7.6: Growth Rate of HC Index



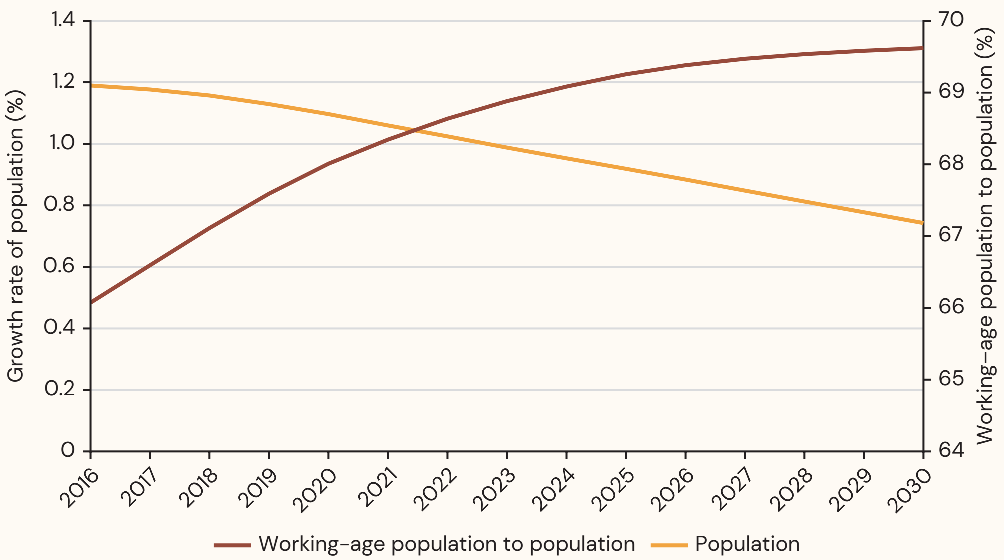
Source: PWT 8.1.

Figure 7.7: Growth Rate of TFP



Source: PWT 8.1, GTAP.

Figure 7.8: Growth Rate of Population and Working Age to Population



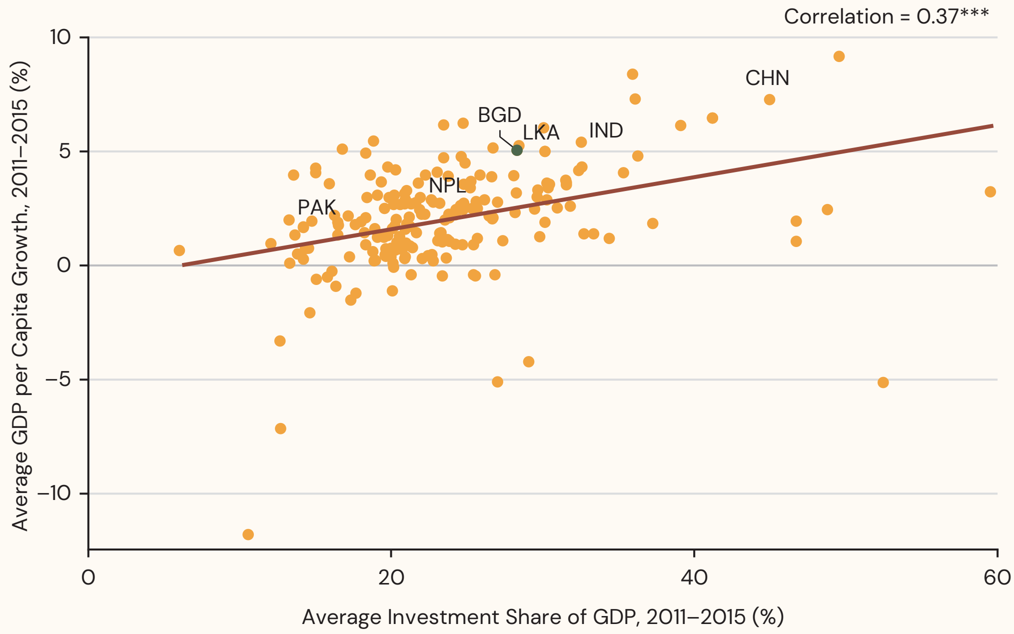
Source: World Bank Human Development Network.

Indicators database.[6] The relationship between the two variables is positive and highly significant. However, a more important question is whether capital accumulation can deliver a sustainable high level of growth going into the future.

Average investment as a share of GDP for the country during 2011–2015 was upwards of 28 percent, and the country delivered higher growth than what is expected at that level of investment. The country has a higher investment rate compared to Pakistan and Nepal but lags behind China and India. This suggests

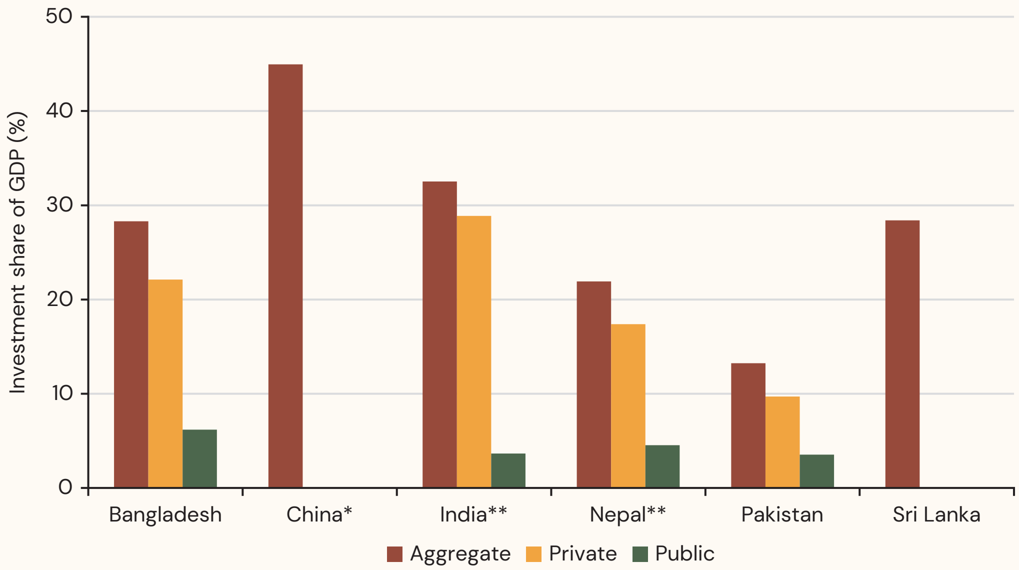
[6] Note that for some countries data for 2015 are not available, in which case the average reflects the average during 2011–2014.

Figure 7.9: Average GDP per Capita growth versus Average Investment Share of GDP



Source: World Development Indicators (***Significant at 1%).

Figure 7.10: Investment Share of GDP



Source: World Development Indicators.
Note: *Aggregate average of 2011–2014, **All measures average of 2011–2014.

that the country has some room to expand its investment share of GDP. However, as can be seen from figure 7.10, the deficit in investment share with respect to India is not due to low public investment in Bangladesh. Average public investment as a share of GDP during 201 2014 outpaced that of India by more than 2.5 percentage points. The targets from the 7th Five Year Plan are used to chart a reasonable path of investment. Specifically, I assume that the aggregate investment share of GDP increases from the present levels to 34.4 percent of GDP by the year 2020 and remains at that level beyond 2020. This is based on the plan targets on public investment, which rises from 6.5 percent of GDP in 2016 to 7.8 percent of GDP by the year 2020. This implies that private investment as a share of GDP expands by approximately 3 percentage points to reach 26.6 percent by 2020. I assume that both public and private investment continue to remain at the same level beyond 2020.

With regards to investment, there is a concern that public investment is not as efficient as private investment. This means that a percentage point expansion in public investment will deliver lower growth compared to a percentage point expansion in private investment. On the other hand, it is possible to generate additional growth by increasing the efficiency of public investment. To capture the differences in efficiency across public and private investment, it is assumed that a unit of public investment I_t^G equals only a fraction $q \in (0,1)$ of private investment I_t^P which is perfectly efficient. The total effective investment I_t is given by

$$I_t = qI_t^G + I_t^P \tag{9}$$

There are many studies that have studied the efficiency of the public sector (for example Afonso et al. 2005, 2010). The quantitative findings from these studies can be used to discipline the parameter governing the efficiency of public investment q. Afonso, Schuknecht, and Tanzi (2010) report that for the sample countries, the same level of public sector output can be produced using 41 percent less resources on average. This implies a capital efficiency of 59 percent. The efficiency of public investment for Bangladesh is assumed to be a bit lower than the mean efficiency at 55 percent because the developing countries in the sample have lower efficiency rates.

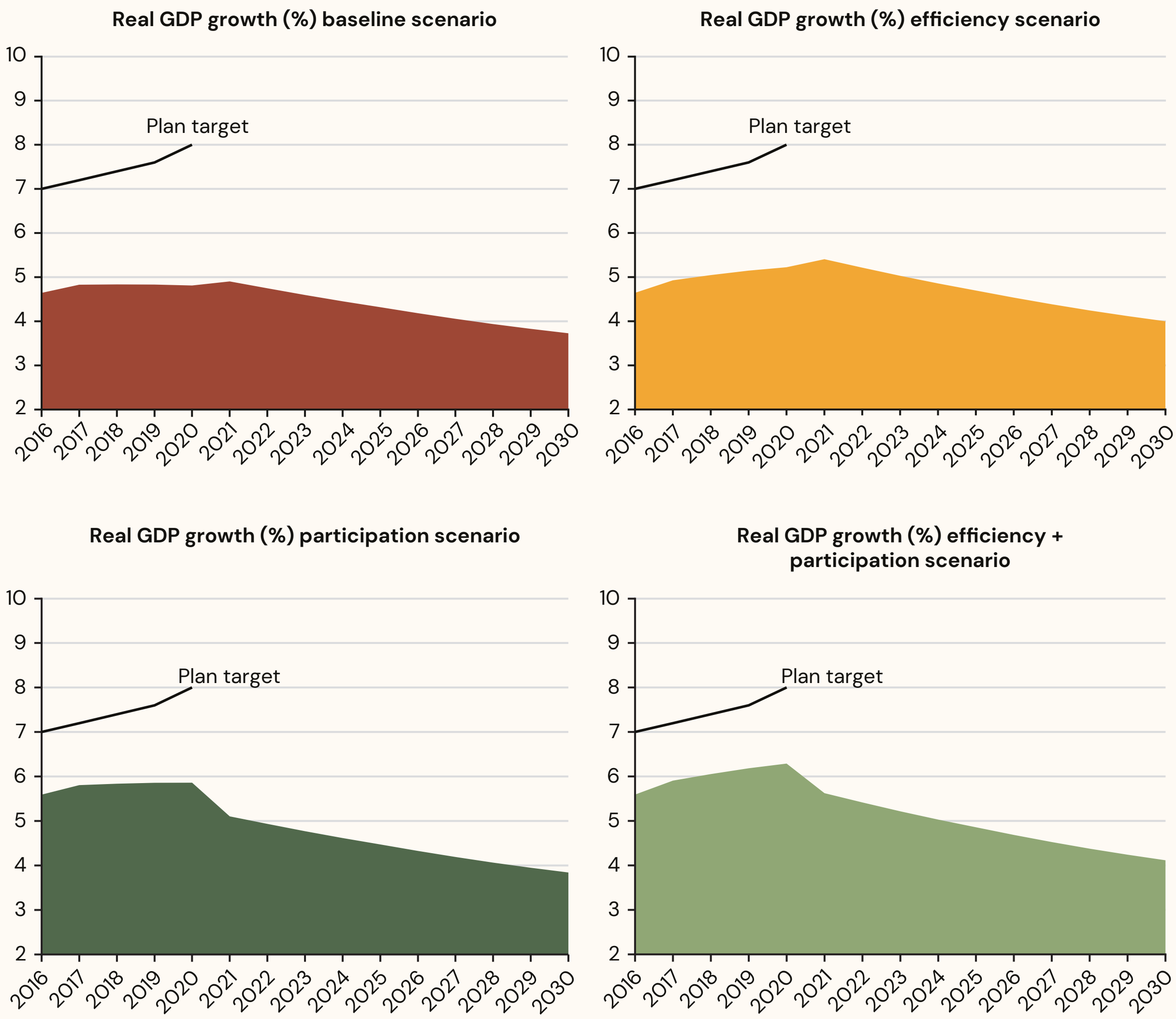
- **Participation rate: ρ_t.** The aggregate participation rate is the weighted average of the male and female participation rates. The male labor force participation rate in the country has remained near 80 percent for many decades and is similar to what is observed in many countries worldwide. On the other hand, the female labor force participation stands at 34 percent and has considerable room for improvement. The country has achieved around a 10 percentage point increase in female labor force participation during the last decade and provides a basis for further expansion going forward. However, I analyze the prospective expansion in the female labor force participation separately in order to isolate its impact on growth.

I construct the following four scenarios in order to quantify the growth impact of improvements in investment and female labor force participation. Note that all other variables, such as growth rate of human capital per worker, growth rate of TFP, and so forth are unchanged across scenarios and follow the time path as previously defined.

- **Baseline Scenario:** Public and private investment share of GDP rises according to 7th Five Year Plan targets till 2020 and remains at the 2020 level going forward. The efficiency of public investment remains at 0.55 throughout and there is no change in the female labor force participation rate.
- **Efficiency Scenario:** Public and private investment follow the same path as in the Baseline Scenario, and the efficiency of public investment grows linearly from 0.55 in 2015 to 1.00 in 2020. There is no change in the female labor force participation rate.
- **Participation Scenario:** Public and private investment follow the same path as in the Baseline Scenario, and the female labor force participation rate grows linearly from 34 percent in 2015 to 45 percent in 2020. There is no change in the efficiency of public investment.
- **Efficiency + Participation Scenario:** Public and private investment follow the same path as in the Baseline Scenario, and the efficiency of public investment grows linearly from 0.55 in 2015 to 1.00 in 2020. The female labor force participation rate also grows linearly from 34 percent in 2015 to 45 percent in 2020.

The simulation results corresponding to the four scenarios are shown in figure 7.11. Apart from demographic changes, the only drivers of growth operating in the Baseline Scenario are capital accumulation and growth of human capital per worker. The GDP growth rate increases marginally till 2021, driven by an

Figure 7.11: GDP Growth under Baseline, Efficiency, Participation and Efficiency & Participation Scenarios



expanding investment share of GDP. The GDP growth rate remains below the 5 percent mark for the entire period till 2021. The growth rate starts declining past 2021 and falls below 4 percent in 2028. In addition to the forces driving growth in the Baseline Scenario, the linear rise to efficiency of public investment provides a further push to economic growth. Similar to the Baseline Scenario, the growth rate increases till 2021 and is slightly higher than the Baseline Scenario. The GDP growth rate peaks in 2021 under both scenarios, at which time the growth under the Efficiency Scenario outperforms the growth under the Baseline Scenario by more than one-half a percentage point. Even though public investment is a small share of the aggregate investment, an increase in its efficiency has a non-trivial impact on economic growth.

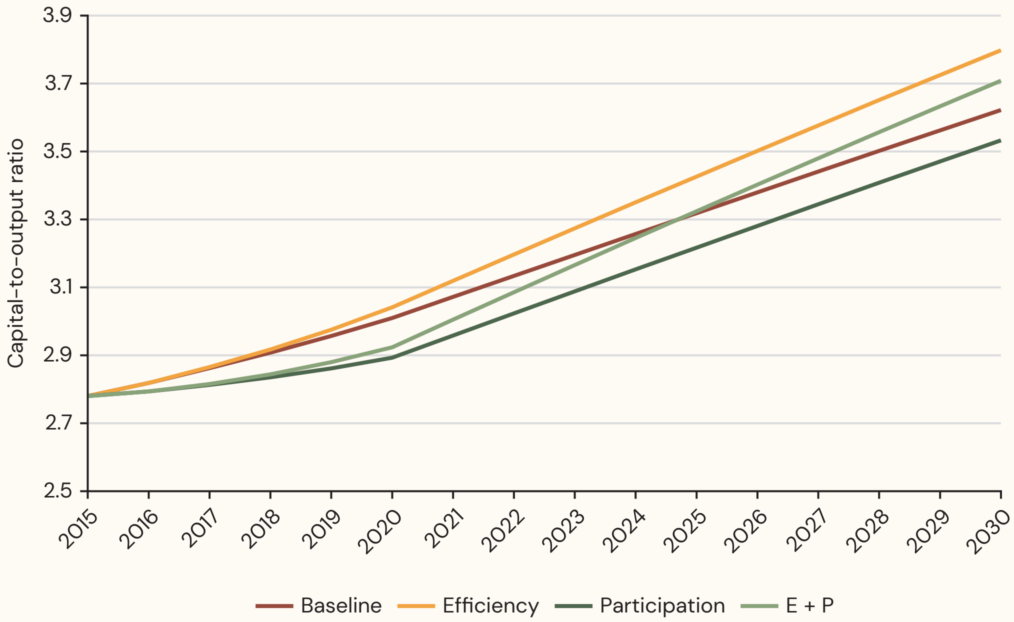
The efficiency of public investment is unchanged under the Participation Scenario. Instead, the aggregate participation rate rises, driven by improvements in female labor force participation. The growth rate under the Participation Scenario rises somewhat till 2020 and its behavior is very similar to the growth under the Baseline Scenario. However, the linear increase in the female labor force participation rate means that growth is higher compared to the Baseline Scenario. The 11 percentage point increase in female labor force participation spread across five years on average adds more than 1 percentage point to GDP growth each year. The growth rate declines by about 75 basis points in 2021, as growth in the participation rate comes to an end. Like the previous scenarios, the growth rate continues to decline gradually and falls below 4 percent by 2029. The last scenario considers the joint impact of improvements in the efficiency of public capital and female labor force participation rate. Similar to the Efficiency Scenario, the growth rate increases faster compared to the Baseline and Participation scenarios. In addition, the growth rate starts at a higher level, owing to the impact from the higher participation rate. The growth rate declines gradually beginning in 2022, but unlike previous scenarios the growth rate manages to remain above the 4 percent mark by 2030.

An important point to consider here is that the growth rate under all scenarios starts declining after the first few years. Equation (8) illustrates why this happens. Keeping everything constant, an increase in the capital-to-output ratio will lead to lower growth. This means that if capital is growing faster than output, the growth rate will be on a downward trajectory. Figure 7.12 plots the capital-to-output ratio for the different scenarios. Note that the capital-to-output ratio is increasing throughout for every single scenario. This rising capital-to-output ratio creates drag on the growth rate. In the first few years, the negative impact of the rising capital-to-output ratio is offset by increases in investment share, efficiency of public capital, and/or female labor force participation. However, as these sources cease to operate in the later years, the rising capital-to-output ratio chips away at the growth rate. In this respect, it is important to understand a secondary role of growth drivers other than investment. Not only do these drivers of growth create growth directly, they also provide downward pressure on the capital-to-output ratio. In this way, they indirectly ensure that investment remains relatively productive in generating growth.

3.1.1 Introducing TFP Growth

The important finding from the four scenarios is that the implied growth rate falls short of plan targets even under the most optimistic scenario. The average annual growth rate during 2015–2020 averages a little over 6 percent. It appears that achieving growth rates in excess of 7 percent is not possible without further contributions from other sources. An important driver of growth, which is missing from the simulations, is the growth in TFP. The importance of TFP growth is based on two factors discussed previously. First, as

Figure 7.12: Capital-to-Output Ratio under Baseline, Efficiency, Participation and Efficiency & Participation Scenarios



noted in equation (8) the TFP growth has the largest direct effect on growth, where a 1 percentage point increase in TFP leads to a 1 percentage point increase in the growth rate of output per capita, and second, a growth in TFP adds to output without changing the level of capital in the economy, thereby pushing the capital-to-output ratio down and making investment more productive. While the average annual TFP growth in the country during 2001–2011 has barely been upwards of zero, the upward trend during the period suggests that the country can achieve a positive TFP growth rate for an extended period of time if appropriate reforms are enacted. Two additional growth scenarios are carried out to quantify the impact of TFP growth on economic growth:

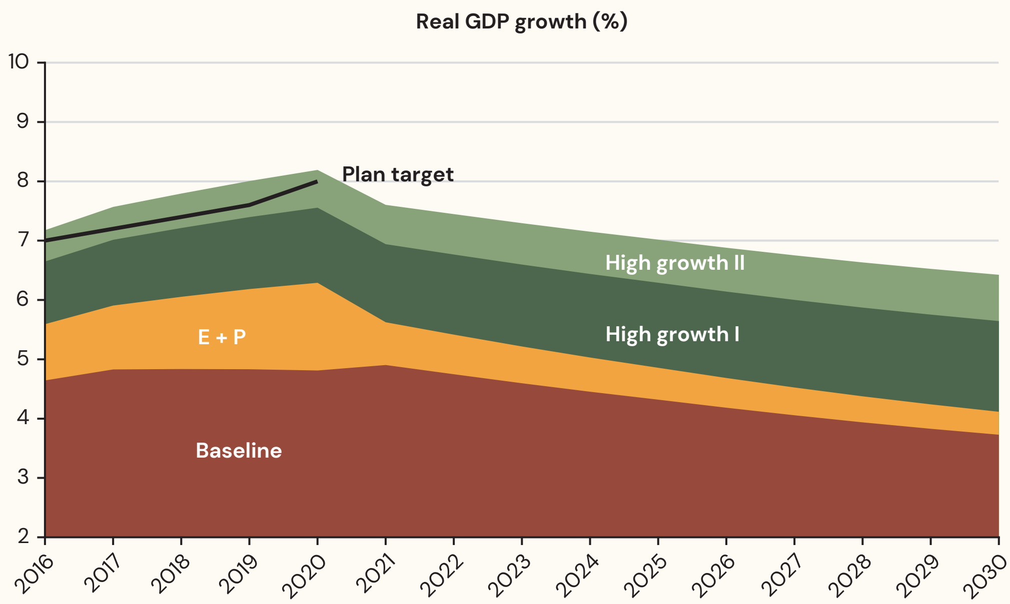
- **High Growth Scenario I:** Annual growth rate of TFP = 1.0 percent
- **High Growth Scenario II:** Annual growth rate of TFP = 1.5 percent

All other variables including efficiency of public capital and female labor force participation are assumed to follow the time path outlined in the Efficiency + Participation Scenario.

To gauge how realistic an annual increase of 1.0–1.5 percent in TFP is, consider the finding in Bernanke and Gurnayak (2002). The authors show that only 5 percent of the countries in the world were able to achieve a TFP growth of 2 percent per year on average for during 1965–1995.[7] While the two High Growth scenarios lie within the range of what has been achieved by other countries in the past, it is noteworthy that only a handful of countries have managed to do so. Achieving a high TFP growth for a sustained period will require a continued focus on reforms and technology advancement.

Figure 7.13 shows the result of the exercise and compared the growth scenarios in presence of TFP growth to the Baseline and Efficiency + Participation scenarios. With an annual TFP growth rate of 1 percent, the GDP growth rate breaches the 7 percent mark and averages around 7.15 percent during 2016–2020, which is just below the plan targets. The GDP growth rate declines past 2020 as the female labor force participation rate stabilizes. Yet, the growth rate remains above 6.5 percent for many periods. The implied growth rate

Figure 7.13: GDP growth under Baseline, E+P, High Growth I & II scenarios



[7] The estimated average annual TFP growth for Bangladesh during the period ranged between 0.1–0.5 percent across the various methods considered by the authors.

Figure 7.14: Capital-to-Output Ratio under Baseline, E+P, High Growth I & II scenarios

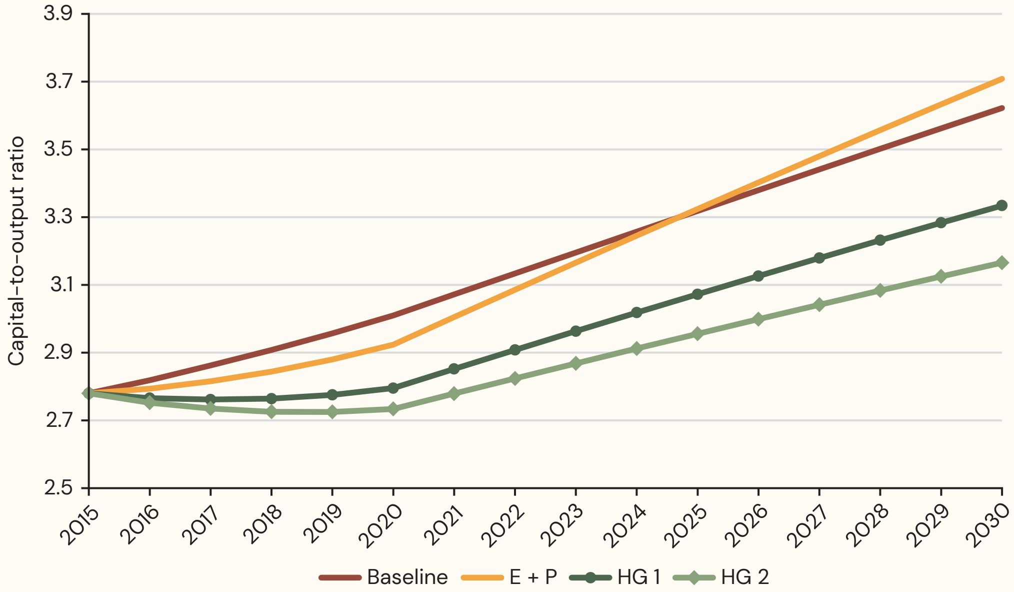


Table 7.1: Average Annual Real GDP Growth under Different Scenarios

	Average Annual Real GDP Growth (%)		
Scenario	**2016–2020**	**2021–2025**	**2026–2030**
Baseline	4.79	4.60	3.95
Efficiency	5.00	5.04	4.26
Participation	5.79	4.78	4.07
Efficiency + Participation	6.01	5.23	4.39
High Growth I	7.17	6.61	5.88
High Growth II	7.75	7.30	6.64
7th Five Year Plan Target	**7.44**	—	—

is above the plan target when TFP grows by 1.5 percent per year. The average annual growth rate under High Growth Scenario II during the plan period outpaces the average annual plan growth rate by more than 30 basis points. The growth rate remains above the 7.0 percent mark for many years and does not fall below 6.5 percent even after 15 years. Table 7.1 summarizes the growth outcomes under various scenarios.

It is interesting to note that the difference in average growth rates between High Growth Scenarios I and II, and the Efficiency + Participation Scenario increases with time. This happens because the gap in capital-to-output ratios between the former and the latter increases with time as additional growth achieved via TFP increases, which does not add to capital accumulation (Figure 7.14).

In summary, sustaining a high growth rate requires a sustained increase in TFP growth. An investment-led strategy coupled with improvements in efficiency of public capital will deliver a growth of 5 percent for the next decade. However, maintaining an investment share of GDP beyond 2025 will deliver lower than a 5 percent growth as capital-to-output ratios keep growing, making investment less productive.

3.2 Required Investment given Growth Targets

The focus of the previous section was to obtain a growth rate consistent with a set of assumptions on growth drivers. In this section, I ask what assumptions on growth drivers are required to deliver a desired time path of GDP growth. As there are multiple drivers of growth, I use the model to solve for the implied investment share of GDP, assuming time paths of other drivers. The goal of the exercise is to determine whether the time path of the implied investment share of GDP is feasible for the country or not.

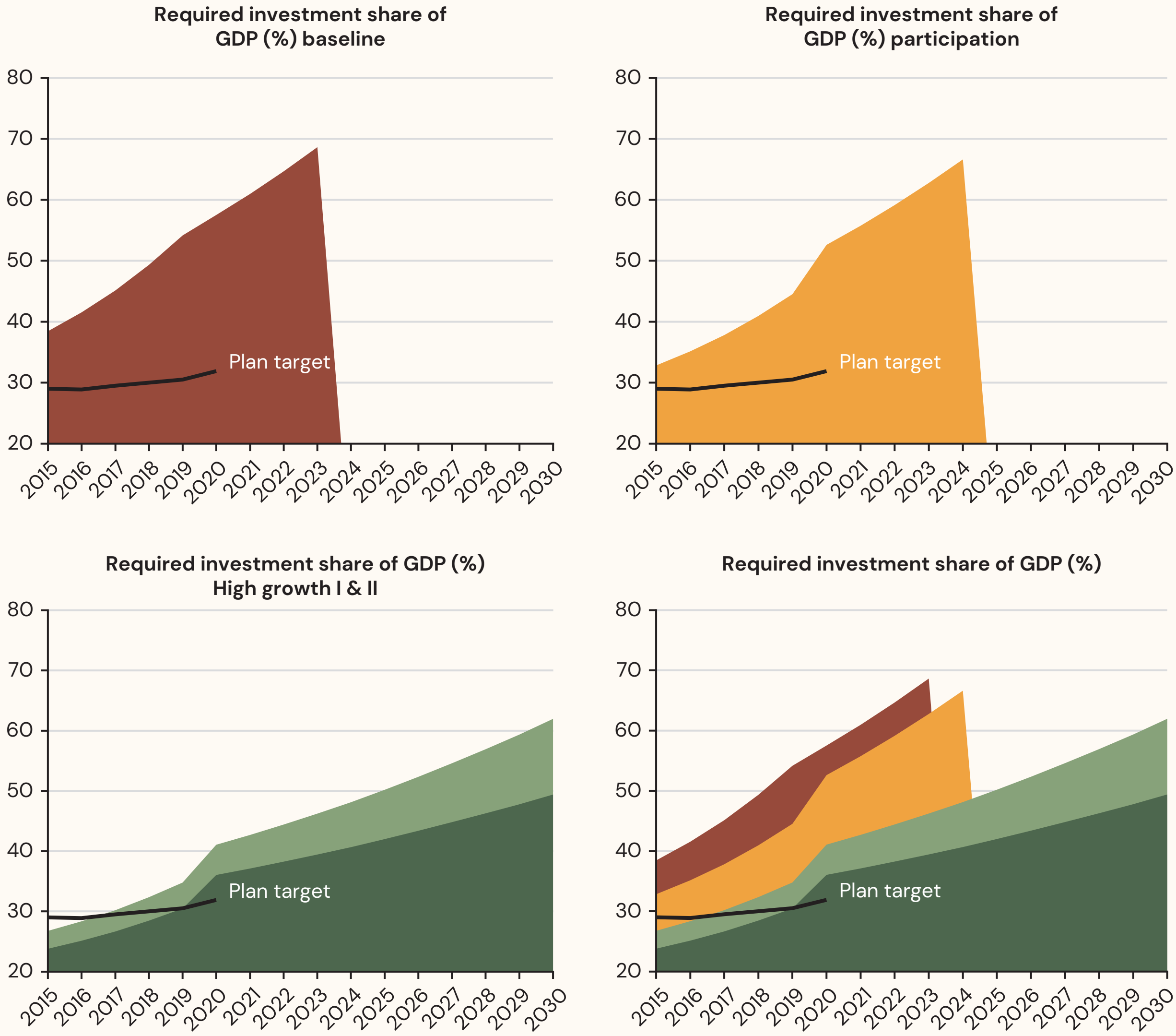
The first step here is to choose a desired path of GDP growth, and it is selected based on the 7th Five Year Plan targets. In line with the plan targets, the desired GDP growth rate increases steady from 7 percent in 2016 to reach 8 percent by 2020. The desired GDP growth path remains at 8 percent from then onward. Like in the previous exercise, four different growth scenarios are considered:

- **Baseline Scenario:** All variables, for example the growth rate of human capital per worker, follow the same path as in the Baseline Scenario of the previous exercise. Note that the investment share of GDP, which was an input in the previous exercise, is the output of this exercise.
- **Participation Scenario:** Except for the female labor force participation rate, all other variables follow the same path as in the Baseline Scenario. The female labor force participation rate grows linearly from 34 percent in 2015 to 45 percent in 2020.
- **High Growth Scenario I:** Except for TFP growth, all other variables follow the same path as in the Participation Scenario. TFP grows by 1.0 percent each year.
- **High Growth Scenario II:** Except for TFP growth, all other variables follow the same path as in the Participation Scenario. TFP grows by 1.5 percent each year.

The results of the simulation are shown in figure 7.15. Barring demographic changes, the only driver of growth operating in the Baseline Scenario is the growth of human capital per worker. The previous exercise showed that the 7th Five Year Plan targets will fail to deliver planned GDP growth under the Baseline Scenario. Not surprisingly, figure 7.15 shows that the required investment share of GDP that delivers planned growth overshoots planned investment. However, the more important finding is the stark gap in required investment and planned investment. The required investment share of GDP exceeds the planned investment share by more than 13 percentage points in 2016 and rises steadily to cross 25 percent by 2020. The required investment share rises fast over time and reaches unfeasible levels soon and reaches almost 65 percent by 2022. The gap between the required investment and planned investment is somewhat lower under the Participation Scenario as steady increases in the female labor force participation rate share the burden of delivering high desired growth. Yet, the require investment share of GDP exceeds the planned investment share significantly, and the gap between the two cross the 20 percent mark in 2020. Though lower than the required investment share in the Baseline Scenario, the investment share under the Participation Scenario also reaches unfeasible levels soon enough and crosses the 65 percent mark in 2024. These results suggest that targeting sustainable GDP growth rates in the 7–8 percent range via boosting investment without TFP growth is bound to result in disappointment.

Like in the previous section, the quantitative findings here are to inform that high TFP growth is essential if high levels of GDP growth are to be achieved, as TFP growth keeps required investment within feasible limits. The required investment share of GDP is close to planned investment share when TFP grows by 1.5 percent each year. In fact, barring the last plan year, the planned investment share exceeds or remains close to the required investment share. The growth of the required investment share is muted in the presence of TFP growth compared to the earlier two scenarios as TFP growth keeps the capital-to-output ratio low, thereby maintaining the productivity of expanding capital stock. However, sustaining 8 percent growth for a long period of time may still prove challenging, as the required investment share crosses 60 percent of GDP and reaches almost 50 percent of GDP under High Growth Scenarios I and II, respectively.

Figure 7.15: Required Investment Share of GDP under Baseline, Participation and High Growth I & II Scenarios



3.3 Growth Led by External Sector

In the version of the LTGM applied above (submodels 1 and 2), the external sector plays no direct role in generating growth. This happens because the investment rate is fed exogenously into the model, which does not respond to changes in the external sector. A shortcoming of this approach is that it is not possible to analyze growth that may be derived through foreign investment and external borrowing. To overcome this challenge, in Submodel 3 of the LTGM, investment is made endogenous so that investment depends on national savings and funding from external sources. This is done using two simple external sector conditions.

The first external constraint requires that investment I_t is the excess of national savings S_t over the current account balance CAB_t:

$$I_t = S_t - CAB_t \tag{10}$$

Equation (10) suggests that investment can be greater than national savings if the economy is able to run a current account deficit. The current account balance can be further decomposed as the acquisition of net foreign assets NFA_t less the incurrence of net foreign liabilities NFL_t:

$$CAB_t = \Delta NFA_t - \Delta NFL_t$$

For simplicity, it is assumed that there are no changes in the stock of net foreign assets ($\Delta NFA_t = 0$). The change in net foreign liabilities equals the flow of foreign direct investment FDI_t augmented by the accumulation of the external debt during the period. Incorporating these in the previous equation gives:

$$CAB_t = FDI_t + (D_t - D_{t-1}) \tag{11}$$

Substituting the value of CAB_t from equation (11) in equation (10) and dividing both sides by Y_t yields the relationship between investment, national savings, and the external sector in terms of share of GDP:

$$\frac{I_t}{Y_t} = \frac{S_t}{Y_t} + \frac{FDI_t}{Y_t} + \left[\frac{D_t}{Y_t} - \frac{\left(\frac{D_{t-1}}{Y_{t-1}} \right)}{\left(1 + g_{y,t}^{pc}\right)\left(1 + g_{N,t}\right)} \right] \tag{12}$$

Equation (12) captures the fact that investment can be boosted via three channels—increase in national savings, increase in foreign direct investment, and increase in external debt.

The time paths of national savings, foreign direct investment, and external debt are taken from the 7th Five Year Plan targets which are summarized below:

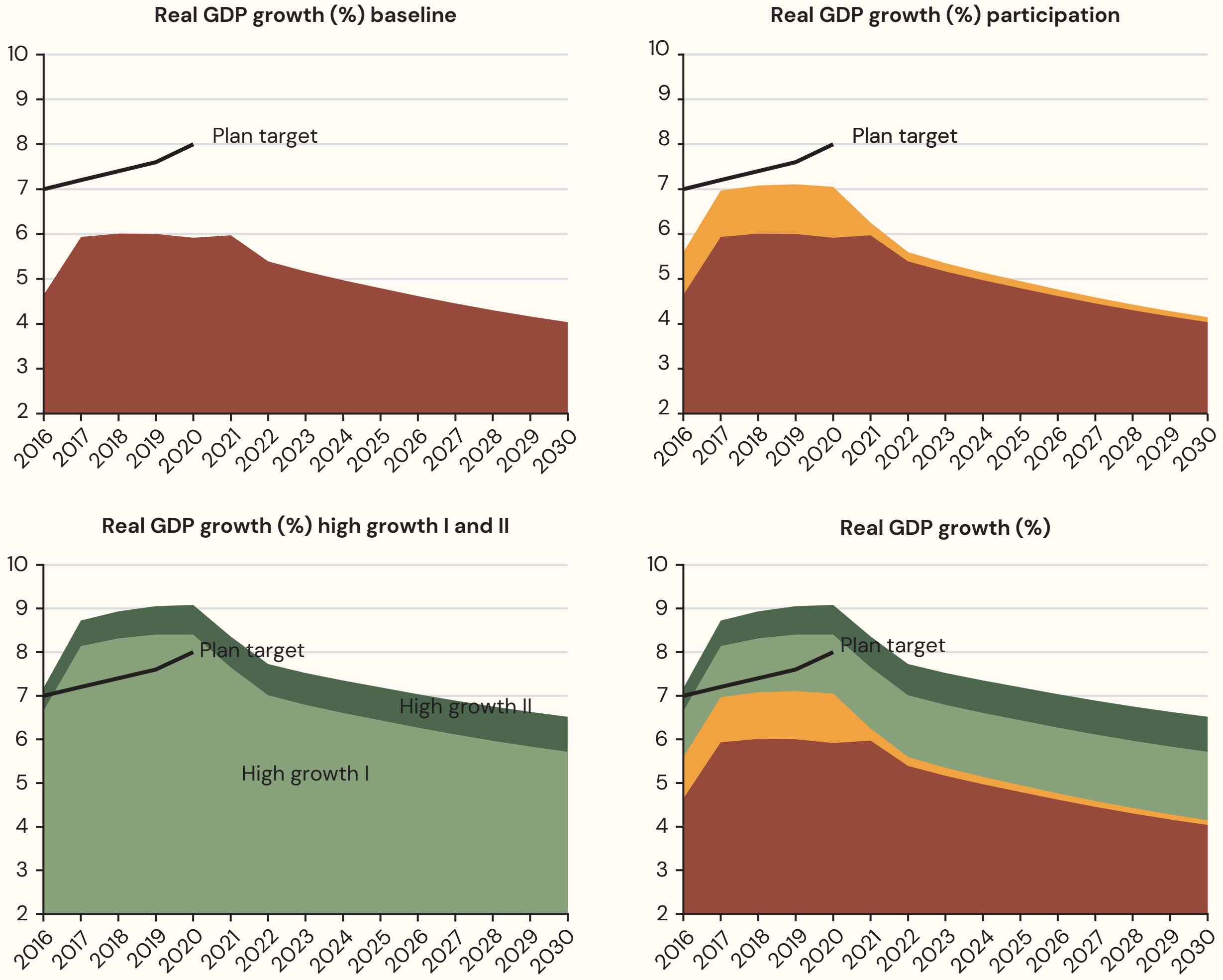
- Starting from 29.0 percent in 2015, savings to GDP rises to 31.9 percent by 2020
- Starting from 0.9 percent in 2015, FDI to GDP rises to 3.0 percent by 2020
- Starting from 25.1 percent in 2015, external debt to GDP rises to 37.4 percent by 2020

All the above variables are assumed to remain at the 2020 level from that year onward. Like in the previous section, four alternative growth scenarios are considered—Baseline, Participation, and High Growth Scenarios I and II.

Figure 7.16 shows the GDP growth paths under different scenarios when investment responds to the external sector. The behavior of growth paths under various scenarios is very similar to the behavior seen earlier in section 3.1. An aspect of difference is the sudden jump in growth rate in 2017, which was absent in the previous case. This happens because the GDP growth during 2016 is a function of investment made in the previous year, which is the same across the two exercises. Investment becomes responsive to the external sector beginning in 2016, which has a one period delayed impact on growth that shows as the initial bump.

Under the Baseline Scenario, the GDP growth rate crosses the 6 percent mark in two intermediate plan years and averages 5.7 percent during the entire plan period. The growth rate starts declining past 2021 and remains just above 4 percent by 2030. As expected, the growth rate under the Participation Scenario is higher compared to the Baseline Scenario and exceeds it by around 1 percentage point during each of the plan years. The growth rate declines by about 80 basis points in 2021 as the growth in the participation rate comes to an end. The growth rate continues to decline gradually and is just 10 basis points above the growth rate under the Baseline Scenario in 2030. With an annual TFP growth rate of 1 percent, the GDP growth rate breaches the 8 percent mark in 2017 and averages just below 8 percent during 2016–2020. The GDP growth rate declines past 2020 as the female labor force participation rate stabilizes. Yet, the growth rate remains above 6.5 percent for many periods. The implied growth rate is above the plan target when TFP grows by 1.5 percent per year. The average annual growth rate under the High Growth II Scenario during

Figure 7.16: GDP Growth under Baseline, Participation and High Growth Scenarios when Investment Responds to External Sector



the plan period outpaces the average annual plan growth rate by more than 1 percentage point during most of the plan years. The growth rate remains above the 7.0 percent mark till 2026 and does not fall below 6.5 percent even after 15 years.

The implied investment share of GDP obtained using equation (12) is higher than the investment shares used in section 3.1. While the national savings as a share of GDP is lower than the investment share, even under the assumption that public capital is perfectly efficient ($q = 1$), this is more than offset by the foreign direct investment (FDI) assumed to flow in each year. With an expanding external debt to GDP ratio, the implied investment share becomes even larger compared to the assumed path of investment share in section 3.1. This implies that the obtained growth path for a particular scenario will be higher compared to the corresponding scenario in which the investment is independent of changes in the external sector. This can also be seen by comparing the five year average rates shown in table 7.2 to the corresponding table 7.1 presented in section 3.1.

In summary, all exercises underline the importance of a sustained high TFP growth in attaining a sustained high GDP growth. An investment-led strategy by itself will not be able to deliver high growth for many years as, without other factors driving growth, a resulting increase in capital-to-output ratio will keep chipping

Table 7.2: Average Annual Real GDP Growth under Different Scenarios

	Average Annual Real GDP Growth (%)		
Scenario	**2016–2020**	**2021–2025**	**2026–2030**
Baseline	5.70	5.26	4.31
Participation	6.76	5.46	4.44
High Growth I	7.98	6.90	5.98
High Growth II	8.59	7.63	6.77
7th Five Year Plan Target	**7.44**	—	—

at the growth impact of investment. Given the importance of TFP growth, it is essential to identify factors that can generate high TFP growth growing forward. In the next section, I examine the quantitative impact of one such factor—a more efficient allocation of existing resources across sectors.[8]

4. TFP Growth and Resource Allocation across Sectors

Average labor productivity in agriculture is less than one-fourth compared to average labor productivity in both industry and services. While the employment share of agriculture has shrunk by around 6.5 percentage points during the last 15 years, the country still employs 44 percent of its workforce in the relatively unproductive agricultural sector. The huge gaps in productivity across sectors are symptoms of a misallocation of resources, and economic growth can be achieved simply by moving resources out of agriculture to the other sectors.

While there are large gaps in average productivity, allocative efficiency requires a convergence in marginal productivity across sectors. Assuming Cobb-Douglas production technologies at the sector level, together with perfect competition in factor markets, the measurement of marginal productivity reduces to adjusting the average products of a sector with the sector-specific labor share of income. Table 7.3 shows the marginal productivity in industry and services relative to agriculture for Bangladesh, which have been computed using labor shares of income at the sector level from the GTAP database. While there has been little change in marginal gaps in industry relative to agriculture since 2000, the productivity gap between services and agriculture has been on the rise. This is a direct consequence of the fact that the services' share of value added has expanded without a corresponding increase in the services' share of employment. In fact, the services sector has lost a percentage point of representation in the aggregate employment.

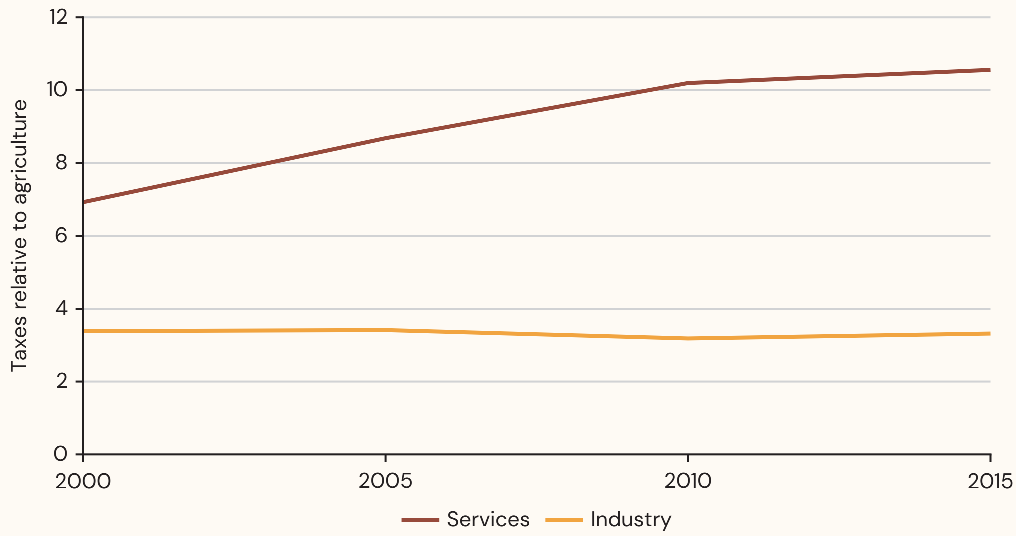
To quantify the impact of reallocation of resources on economic growth, I apply the Sinha (2016) model of resource allocation in which productivity gaps rise as a result of asymmetrical taxes/distortions across sectors. The distortions in the model are a stylized approach to capture the effects of a host of frictions

[8] Please see appendix A.2 for a brief discussion on factors that are important in driving TFP growth. This discussion is a summary of the survey on productivity by Syverson (2011). The interested reader should read the paper, as the discussion here highlights only some of the important factors that can lead to productivity growth and in no way provides a comprehensive listing of such factors.

Table 7.3: Marginal Labor Productivity in Industry and Services (relative to Agriculture)

	Marginal Productivity of Labor Relative to Agriculture			
	2000	2005	2010	2015
Industry	4.38	4.41	4.19	4.32
Services	7.93	9.68	11.20	11.56

Figure 7.17: Distortions/Taxes in Industry and Services (relative to Agriculture)



that restrict movement of resources across sectors. The distortions disappear if there are no frictions to movement of resources across sectors. To the extent that these distortions are positive for a particular sector, when measured relative to agriculture, they imply a barrier to movement of resources out of agriculture and vice versa. Figure 7.17 plots these taxes for industry and services relative to agriculture. The trend in distortions captures the trend in marginal productivity gaps seen in table 7.3.

In order to quantify the gains from a better resource allocation, I perform a simple counterfactual exercise. I ask how much economic growth can be achieved by Bangladesh if the present level of distortions in the country are changed to what is observed in peer countries.[9] Table 7.4 below reports the counterfactual growth in real GDP per capita, together with distortions that deliver this growth. Real GDP per capita will more than double if the distortions in the country are reduced to the levels observed in China. On the other hand, real GDP per capita has the potential to increase by about 20 percent if distortions equal what is observed in India, which has a similar level of distortions in industry but much lower distortions in services.

In the next section, I discuss how fiscal policy can be incorporated in the model and analyze different growth scenarios in terms of sustainability of the government debt position.

[9] The estimates of distortions for peer countries have been taken from Sinha (2016).

Table 7.4: Distortions Relative to Agriculture and Counterfactual Growth

	Distortions relative to agriculture		
	Industry	Services	Counterfactual growth (%)*
Bangladesh	**3.32**	**10.56**	
China	–0.76	–0.77	117
India	4.17	5.76	19
Indonesia	3.94	2.74	45
Malaysia	0.59	0.44	82
Pakistan	0.58	2.81	41
Sri Lanka	3.08	6.74	14

Note: *The counterfactual growth for Bangladesh represents the implied percentage change in output when the relative distortions in both sectors are changed to what is reported in comparable countries.

5. Analysis of Fiscal Policy

The LTGM (submodel 3) can be used to infer what the implied growth paths spell for the sustainability of the government debt position. The country has a low government debt to GDP ratio, which stood at 34 percent at the end of 2015. The ratio is linked to the model through the denominator term. The higher the growth rate of GDP, the lower is the ratio. The time path of government debt to GDP can be solved for using the relationship between primary balance and government debt.

The government debt in the next period D_{t+1}^G equals the debt in the previous period D_t^G after deducting the primary balance surplus PB_t of the previous period net of the interest payments IP_t. Note that there is a net addition to government debt if the government runs a primary deficit. The government debt accumulation equation can be written as:

$$D_{t+1}^G = D_t^G - (PB_t - IP_t)$$

Dividing both sides of the above equation by GDP next period Y_{t+1} and using the growth rates, the following debt accumulation equation is obtained that features variables as a fraction of GDP and the growth rates previously considered.

$$\frac{D_{t+1}^G}{Y_{t+1}} = \frac{\frac{D_t^G}{Y_t} - \left(\frac{PB_t}{Y_t} - \frac{IP_t}{Y_t}\right)}{\left(1+g_{y^{pc},t+1}\right)\left(1+g_{N,t+1}\right)} \tag{13}$$

Primary balance is just the excess of government revenues over government expenses after adjusting for interest payments:

$$PB_t = (TAX_t + NTAX_t) - \left(CE_t + I_t^G\right) + IP_t \tag{14}$$

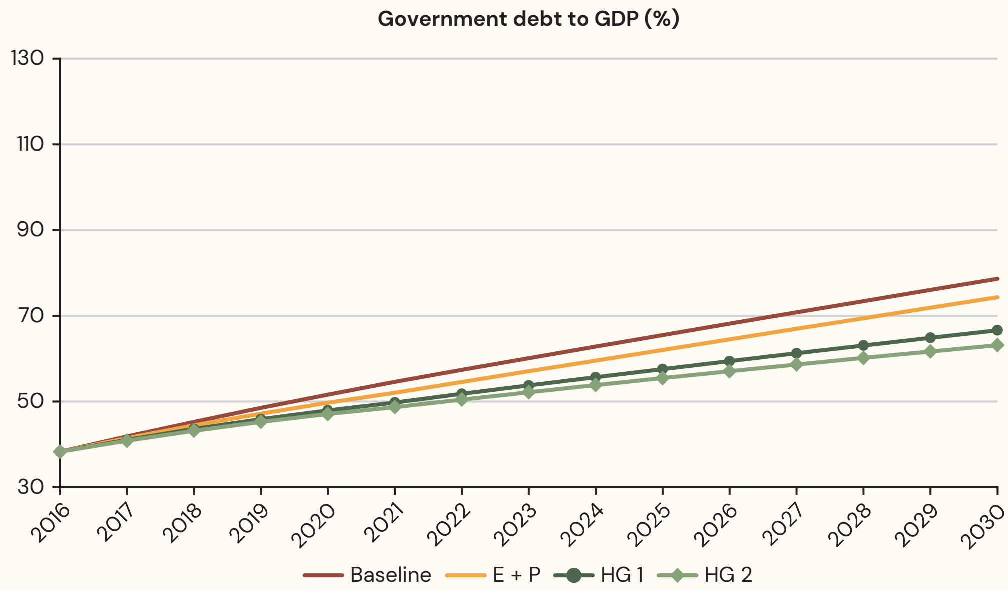
where TAX_t and $NTAX_t$ denote the tax and non-tax revenues, respectively, and CE_t and I_t^G denote the government current expenditure and capital expenditures, respectively. Given assumptions on government operations and using growth rates from the model, the government debt to GDP path can be obtained by employing equation (13).

The simulations in section 3.1 outline the various growth scenarios for the economy. Under the Baseline Scenario, the annual GDP growth rate for the next 15 years varies in the range of 4–5 percent, whereas under the most optimistic High Growth Scenario II the annual GDP growth rate varies in the range of 6.5–8.5 range. An interesting question in this regard is whether such a huge variation in growth rates spells remarkably different implications with regards to the government debt position or not. To make quantitative progress on this front, the time path of government operations needs to be fed into equations (13) and (14). In the spirit of previous sections, the 7th Five Year Plan projections for government operations are used till 2020 after which the variables are assumed to remain at the level targeted in 2020. The assumptions on government operations are summarized below:[10]

- Starting from 9.3 percent in 2015, tax revenue reaches 14.1 percent of GDP by 2020
- Starting from 1.5 percent in 2015, non-tax revenue reaches 2.0 percent of GDP by 2020
- Starting from 10.5 percent in 2015, current expenditures reach 13.9 percent of GDP by 2020
- Starting from 2.0 percent in 2015, interest payment reaches 2.5 percent of GDP by 2020
- Starting from 6.9 percent in 2015, government capital expenditure reaches 7.8 percent of GDP by 2020[11]

The analysis of fiscal policy is carried out for the scenarios listed in section 3.1. Note that in all the scenarios aggregate investment remained the same, while the effective investment differed depending on the efficiency of public capital. Figure 7.18 plots the time path of the government debt to GDP ratio for the different scenarios. The government debt to GDP ratio rises steadily over time as the growth rate of GDP outpaces the growth rate of government debt. The debt ratio rises slower across different scenarios as the growth rate of GDP increases. Under the High Growth Scenario II that features a 1.5 percent annual increase of TFP, the debt ratio rises slowest and reaches just above 63 percent by 2030. In contrast, the debt ratio rises fastest under the Baseline Scenario and closes on the 80 percent mark by 2030. Yet, the government debt situation remains sustainable across all scenarios.

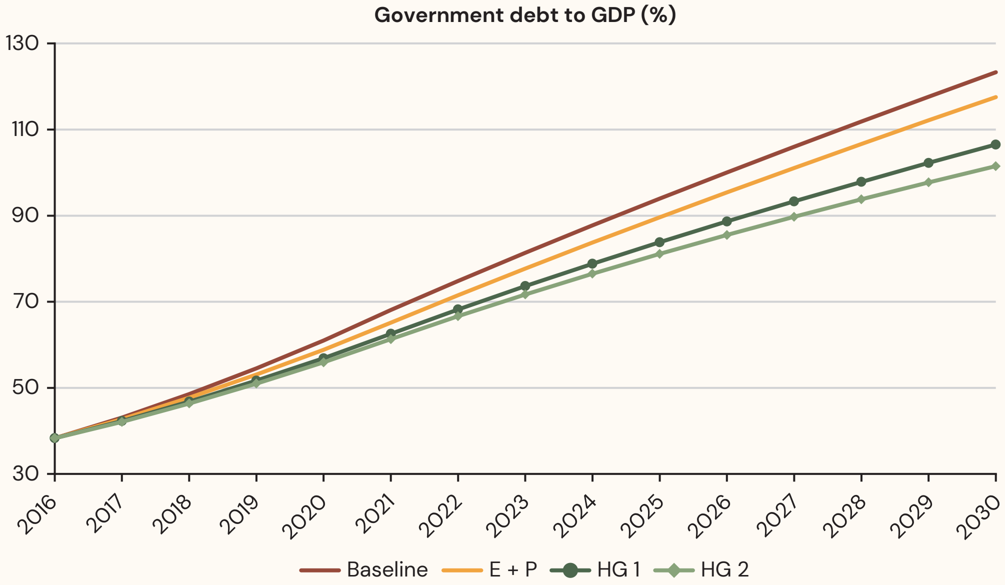
Figure 7.18: Government Debt to GDP under Baseline and other Growth Scenarios



[10] Intermediate year values for all variables correspond to what has been targeted in the Seventh Five Year Plan.

[11] This is consistent with the inputs provided in section 3.1.

Figure 7.19: Government Debt to GDP under Baseline, and other Growth Scenarios (with tax revenue at 9.3 percent)



The discussion above suggests that the sustainability of government debt is a foregone conclusion, as it remains sustainable even if the economy experiences tepid growth going forward. However, such a conclusion overlooks the fact that the debt situation is closely tied to government operations and is not determined only by economic growth. To test whether debt sustainability faces risks if the underlying conditions of government operations are not met, I conduct a simple counterfactual. Specifically, I analyze the risks of government not meeting the tax revenue targets as laid out in the 7th Five Year Plan with regards to the debt situation. Keeping all else the same, I assume that the tax revenue to GDP ratio fails to improve going forward and stays at 9.3 percent. Figure 7.19 illustrates the sharp contrast to the findings above. Like figure 7.18 before, the government debt to GDP ratio is increasing under each scenario but is rising at a much faster rate. The government debt surpasses GDP by 2030 even under the most optimistic High Growth II Scenario and lies just below 125 percent of GDP under the Baseline Scenario.

The debt ratio reaches alarming levels if the revenue targets are not met. Such high debt ratios might bring the sustainability of government debt under serious threat. The exercise shows that the government debt situation is sensitive to government operations and that meeting tax revenue targets is essential in keeping the government debt to GDP ratio in check. The government debt sustainability will face additional risk if the government overshoots its expenditure without making much progress on the revenue front.

6. Conclusion

Bangladesh has achieved a robust economic growth for the last 10 years, with real GDP growing by more than 6 percent on average each year. The magnitude of GDP growth has also come a long way from the 4 percent average annual growth rate of the late 1970s. The economic growth has also coincided with other favorable development outcomes like poverty reduction, literacy growth, etc. However, the more important question going forward is whether the country can maintain high levels of growth seen in the last decade and, if possible, accelerate the growth rate. To quantify the long-term growth prospects of the country, this chapter uses the Long Term Growth Model (as in chapter 1 of this volume). The model is calibrated to match key moments of the Bangladesh economy, and the calibrated model is then used to analyze various growth scenarios.

The main finding of the analysis is that for Bangladesh to sustain a high real GDP growth rate, the country must focus on reforms that drive TFP growth. Even if Bangladesh manages to meet the levels of investment as outlined in the 7th Five Year Plan, it will fail to maintain GDP growth rates achieved in the past decade without a corresponding support from TFP growth. This also means that attaining high GDP growth in the absence of growth in TFP will require investments much higher than planned levels that surpass realistic thresholds very soon.

An important factor that can provide a modest but meaningful contribution to economic growth in the medium term is the growth in female labor force participation. The country has made significant progress in raising the female labor force participation, but there is still massive scope for improvement. An 11 percentage point increase in the female labor force participation rate spread over the next five years can add more than 1 percentage point to GDP growth on average each year.

The model is also used to gain insights on government debt sustainability given different growth scenarios. The analysis highlights the significance of meeting revenue targets while considering the expansion in expenditures. While the government debt for Bangladesh stands at a benign level, it has the potential to rise to cross the level of the country's GDP in the next 15 years if the revenue targets are not met. The sustainability of government debt will come under additional pressure if the actual expenditure overshoots the already increasing planned expenditure.

Appendices are available in Working Paper WPS 7952, or at https://www.worldbank.org/LTGM.

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Chapter 8

Growth in Syria: Losses from the War and Potential Recovery in the Aftermath[1]

Sharmila Devadas, Ibrahim Elbadawi, Norman V. Loayza[2]

Abstract

This chapter addresses three questions: (i) what would have been the growth and income trajectory of Syria in the absence of war; (ii) given the war, what explains the reduction in economic growth; and (iii) what potential growth scenarios for Syria could there be in the aftermath of war? Conflict impact estimates point to negative gross domestic product (GDP) growth of –12% on average over 2011–2018, with output contracting to about one-third of the 2010 level. In post-conflict simulation scenarios, the growth drivers are affected by the assumed levels of reconstruction assistance, repatriation of refugees, and productivity improvements associated with three political settlement outcomes: a baseline (Sochi-plus) moderate scenario, an optimistic (robust political settlement) scenario, and a pessimistic (de facto balance of power) scenario. Respectively for these scenarios, GDP per capita average growth in the next two decades is projected to be 6.1%, 8.2%, or 3.1%, respectively, assuming a final and stable resolution of the conflict.

Keywords: War, conflict, reconstruction, growth, factors of production, Syria.
JEL Codes: D74, F51, 011, 040, 053.

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[2] Sharmila Devadas, World Bank; Ibrahim Elbadawi, Economic Research Forum; Norman V. Loayza, World Bank. Corresponding author email: nloayza@worldbank.org. The paper represents the views of the authors and does not necessarily reflect those of the World Bank, its Executive Directors, or the countries they represent. The authors are grateful to staff of the United Nations Economic and Social Commission for Western Asia, including Ahmad Shikh Ebid for sharing information and data, as well as to Shanta Devarajan, Young Eun Kim, Aart Kraay, Aljaz Kuncic, Rabie Nasser, Khalid Abu-Ismail, and the reviewers and editor of MEDJ for helpful comments. Nurlina Shaharuddin and Izzati Ab Razak provided excellent research assistance. All remaining errors are the responsibility of the authors.

1. Introduction

This chapter addresses three questions. First, what would have been the growth and income trajectory of Syria in the absence of war? Second, given the war, what explains the reduction in economic growth in terms of growth drivers— physical capital, demographics and the labor force, human capital, and total factor productivity? And third, what potential growth scenarios for Syria could there be in the aftermath of war given various assumptions on key growth drivers? Post-conflict, these growth drivers will be affected by the levels of reconstruction assistance and repatriation of refugees, driven, in turn, by potential political settlement outcomes. To obtain plausible quantitative answers to these three questions, the chapter uses an extension of the World Bank Long Term Growth Model (LTGM) that accounts for the role of fundamental growth drivers in a clear and straightforward way. The chapter builds on data and insights by academic researchers and international organizations, such as the United Nations and the World Bank.

The scale and intensity of the violence and destruction associated with the civil war that engulfed the Syrian Arab Republic since 2011 have very few parallels in recent history. The Syrian Observatory for Human Rights (SOHR) estimates the total death toll (from March 15, 2011 to March 15, 2019) at a staggering 570,000 (2.7% of Syria's population in 2010). The United Nations Economic and Social Commission for Western Asia (UN-ESCWA)— which conducted an elaborate sectoral analysis of the economic cost of the Syrian civil war— puts the cumulative destruction of the physical capital stock by end of 2017 at almost US$120 billion (ESCWA 2018), two times the GDP level in 2010 and about five times the GDP level some seven years into the conflict. And in terms of the cost to the overall economy, World Bank (2017) estimates that, from 2011 until the end of 2016, the cumulative losses in gross domestic product (GDP) reached a whopping US$226 billion, about four times the Syrian GDP in 2010. These assessments broadly cohere with calculations of the country's night-light intensity by Ceylan and Tumen (2018) and Li et al. (2017), with the latter suggesting that by 2017, Syria had lost about 80% of its city night-light.

Moreover, in addition to the massive death and destruction, this war has also created an unprecedented number of refugees and internally displaced persons. According to the United Nations High Commissioner for Refugees (UNHCR), there are about 5.6 million registered refugees from Syria in neighboring countries (26% of the population in 2010). However, accounting for unregistered refugees in just the three countries of Egypt, Jordan, and Lebanon would raise the aggregate number to more than 7 million, around one-third of Syria's population in 2010 (UNHCR 2018). Adding these numbers to the roughly 6.3 million internally displaced persons in Syria, we have almost two-thirds of the 21 million Syrian citizens who have been forced out of their homes. To appreciate the global impact of the Syrian refugees and displaced crisis, it suffices to note that the former accounts for more than 23% of the total number of refugees worldwide, while the latter is estimated at 20% of the total number of global internally displaced persons.

The losses incurred by Syria are great, but it is not false hope to look toward recovery and further strengthening of the country's socioeconomic fundamentals beyond its pre-war situation. Chen, Loayza, and Reynal-Querol (2008) conduct a comprehensive evaluation of the aftermath of civil war using event-study analyses across 41 countries over 1960–2003. They show that recovery to pre-conflict levels and further improvements are possible for a country afflicted by war when lasting peace is achieved. Other studies focusing on World War II (WWII) indicate countries returned to their pre-war trends 15 to 20 years post-war (Organski and Kugler 1977, 1980), and that countries suffering large negative output shocks grew systemically faster during the subsequent decades due to reconstruction dynamics (Milionis and Vonyo 2015). Because of the massive destruction of the factors of production in Syria at a scale more common in interstate wars than civil conflicts, the lessons from the post-WWII reconstruction of Europe and insights from modern growth theory could be useful in assessing the post-conflict growth potential for Syria. Jánossy (1969) postulates that fast growth during reconstruction is not only the result of higher returns to physical capital accumulation (which diminish as capital grows in relation to output) but also depends on structural factors like the reorganization of economic activity and the reallocation of production factors. One of the key lessons from the experience of post–WWII growth in the European countries and Japan, for example, was that the rapid growth impact of the massive rebuilding of physical capital was made possible, not only by the Marshall Plan resources, but also by the relatively limited wartime depreciation of the human capital base and technological potential (Smolny 2000).

The implication of the above for the post-conflict economic reconstruction agenda for Syria is that the restoration of human capital should be accorded the highest priority. And this should be alongside the rebuilding of physical capital, which will unavoidably be a key component of the agenda. Further, attention also needs to be paid to other factors contributing to total factor productivity (TFP), including institutions and market efficiency.

However, the prospects for mobilizing meaningful multiyear financing for reconstruction and development and for achieving a critical mass of voluntary refugee returns would hinge on the nature of the ultimate political settlement of the conflict. A lopsided political settlement may deter refugees, with strong lingering uncertainty about security and economic prospects, to return. Some of the main impediments hindering repatriation include the dispossession of refugees' homes and mandatory military conscription for men of age. Therefore, and despite the "invitation" for refugees to return home and the refugee camps being set up within Syria, it is not surprising that only a few thousand returned in 2017, mostly motivated by push factors in the recipient countries. Indeed, this very limited response did not mark the opening of the flood gates for massive repatriation in the following years (POMEPS 2018).

Moreover, the volume of the funding required for reconstruction has been estimated from US$250 billion by the United Nations (UN), more than 10 times the estimated GDP in 2018, to as high as US$1 trillion (POMEPS 2018), by far more than could be provided by Syrian allies. Thus, a genuine reconstruction plan for Syria would best be served by robust support from the wider international community, who have indicated a preference for a more robust political settlement (Elbadawi et al. 2019). The international community can provide some reconstruction aid that would support and encourage the return of refugees, infrastructure investment, and policy reform. This includes aid for geographically dispersed economic reconstruction (such as rebuilding infrastructure and access to health and education) and institutional reform (including security, property rights, and access to justice) that benefits various segments of the population fairly (Yahya and Kassir 2017). Djankov and Reynal-Querol (2010) find that both per capita income and civil war are jointly determined by idiosyncratic country-specific phenomena, some which are of particular relevance to Syria, such as sectarian and ethnic polarization. Consequently, policies are needed to rectify structural problems that make countries, and specifically, Syria more prone to conflict.

Subscribing to the context discussed above, this chapter uses the World Bank Long Term Growth Model–Public Capital Extension (LTGM-PC) by Devadas and Pennings (2019) (and chapter 2 in this volume) to simulate a counterfactual of no-conflict scenario (in section 2), to estimate the impact of conflict (in section 3), and to assess the potential post-conflict growth for Syria (in section 4). The after-war projections are carried out for three political settlement scenarios: a baseline moderate scenario (Sochi-plus, mainly operated by Iran, Russia, and Turkey, with some involvement from the United Nations); a high optimistic scenario (robust political settlement, brokered by the United Nations); and a pessimistic scenario (de facto balance of power).

The LTGM-PC has been developed from another World Bank tool, the Long Term Growth Model (LTGM) (chapter 1 in this volume). In the Standard LTGM, which follows the Solow-Swan growth model, the production function is the traditional Cobb-Douglas specification with aggregate capital and effective labor as imperfect complements. There, public and private capital have the same effect on output. The LTGM-PC extends the Standard LTGM by separating total capital stock into private and public portions, with the former adjusted for quality, while retaining other features of the LTGM, including other growth drivers (demographics and the labor force, human capital, and TFP). The LTGM-PC can be used to analyze the effect of an increase in the quantity or quality of public investment on growth, and to compare the effects of public investment and private investment (see appendix 1 for details).

In the LTGM-PC, the effect of an increase in either the quantity or quality of public investment and the full dynamic growth path depends on country-specific factors, such as the scarcity of public capital (relative to GDP). The model also allows for the fact that public capital stock might be of low-quality construction, which is a practical concern in many developing countries. It contains a new Infrastructure Efficiency Index (IEI) that combines quality indicators for power, roads, and water, as a cardinal measure of the quality of public capital in each country. The LTGM-PC draws extensively on the empirical literature to guide its choice of other parameters, the most important of which is the elasticity of output to public capital, and publicly available databases to calculate key variables. We run all our simulations using the LTGM-PC Excel-based toolkit available at https://www.worldbank.org/LTGM.

Our chapter complements earlier modelling work by World Bank (2017), the most comprehensive study to date on the Syrian toll of war, in four ways. One, it provides a straightforward and transparent analysis of how GDP evolves based on projections for the growth drivers. World Bank (2017) uses a dynamic general equilibrium model to simulate the effects of the conflict through three channels— physical capital destruction, casualties, and economic disorganization, with the last calculated as a residual based on estimated GDP losses. Two, data-wise, we use estimates of physical damage across all types of capital, whereas World Bank (2017) determines destruction in their simulations based on physical damage assessments only in the housing sector. Three, with a greater certainty of the end of conflict, we focus on growth scenarios in the aftermath of war, rather than mostly assessing conflict impact based on different end-time scenarios. Four, we also attempt to provide a more up-to-date assessment of the impact from the conflict, that is until the end of 2018.

Under the counterfactual simulation, our baseline projection shows an average real GDP growth of 5.3% per annum over 2011–2018, which would have led to real GDP rising from US$60 billion in 2010 to US$91 billion and real GDP per capita rising from US$2,857 to US$3,774 by 2018. In contrast, our simulations of the impact of conflict point to a negative annual GDP growth of –12% on average (across all three scenarios, central, lower, and upper estimate projections) over 2011–2018, resulting in a GDP level of US$22 billion in 2018, which is only 24% of the counterfactual GDP level in 2018. Comparing the conflict versus no-conflict simulations suggests a cumulative loss in GDP potential of about US$300 billion over 2011–2018. About 64% of the average negative GDP growth from 2011 to 2018 under the conflict simulation is due to physical capital destruction. Physical capital destruction reflects the compounded effects of large outright damages, low new investments, and a falling output base that is adversely affected by all growth drivers. Demographics and labor account for about 15%, human capital 7%, and TFP 13% of negative GDP growth on average over the conflict years (2011–2018).

In our post-conflict simulations, we assume that the three political settlement scenarios are associated with different levels of reconstruction assistance and different degrees of voluntary mobility of refugees. These in turn affect key drivers of growth: public and private investment and the labor force. We also make different assumptions for human capital growth and TFP growth across the three scenarios.

Depending on the scenarios, our simulation results suggest that it would take between 10 and 20 years for Syria to reach its pre-conflict GDP level and between 10 and 30 years to recover its pre-conflict GDP per capita level (both at 2010 constant prices). If there were to be an unsanctioned and misguided "forced" repatriation of refugees, this would result in significantly lower GDP per capita compared to the voluntary mobility case. Under voluntary return, labor would adjust gradually to capital reconstruction, thus keeping labor productivity from falling.

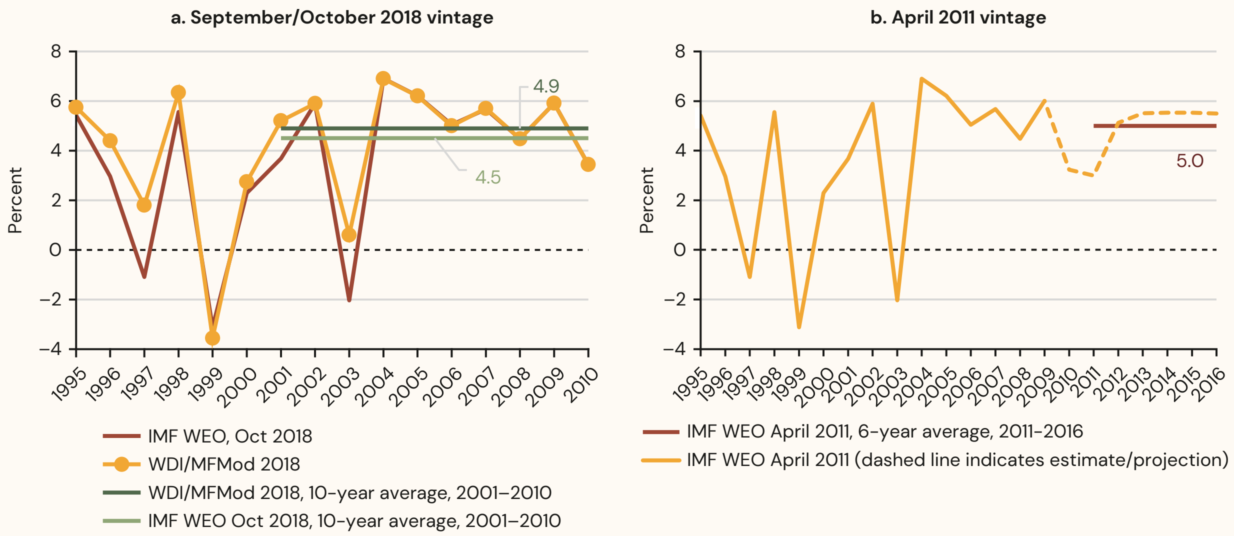
2. Syria Pre-Conflict Developments and Projections

Real GDP growth averaged about 4.7% over 2001–2010 (figure 8.1a).[3] Just prior to the conflict, the International Monetary Fund (IMF) projected robust near-term growth: an average of 5.0% over 2011–2016 (figure 8.1b). This section builds a calibration for a no-conflict scenario using the LTGM-PC, based on pre-conflict developments and projections (where available) in the key growth drivers—physical investment, demographics and the labor force, human capital and TFP.

2.1 Growth drivers

In terms of physical investment, the investment-to-output ratio, I/Y (gross fixed capital formation [GFCF], as a percentage of GDP) averaged about 21.5% over the seven-year period, 2001–2007. For gross capital formation (GCF), which includes inventories as a percentage of GDP, the IMF data showed an average of 23.1% over 2001–2010 (figure 8.2a). Pre-conflict projection data meanwhile suggested a lower average of 21.8% for GCF (% of GDP), albeit with a projected rise of about 3 percentage points over 2011–2016 (figure 8.2b).

Figure 8.1: Pre-Conflict Real GDP Growth and Projection



[3] World Development Indicators (WDI) data for Syria are available up to 2007. For 2008–2010, we use data on GDP growth from the World Bank's internal macroeconomic and fiscal model (MFMod), November 2017 vintage. See Burns et al. (2019) for more information on the model.

The growth rates of total population and the working-age population share averaged 2.5% and 0.8%, respectively, over 2001–2010 based on latest UN estimates (United Nations 2017)— figure 8.3a. As a gauge of projections prior to the conflict, United Nations (2011) indicated average growth rates for these two variables of 1.7% and 1.0%, respectively, over 2011–2020 and 1.5% and 0.3% over 2021–2030 compared to 2.5% and 0.5% over 2001–2010 (figure 8.3b).

The labor force participation rate (LFPR) had been moderating, declining from 54.5% in 1995 to 44.9% in 2010, with an average growth over 2001–2010 of –1.5% (figure 8.4a). This phenomenon occurred despite relatively strong economic growth, distinguishing Syria from other countries— no other Middle East and North Africa (MENA) economy had a similar rate of decline in the LFPR over the same period,

Figure 8.2: Pre-Conflict Investment and Projection

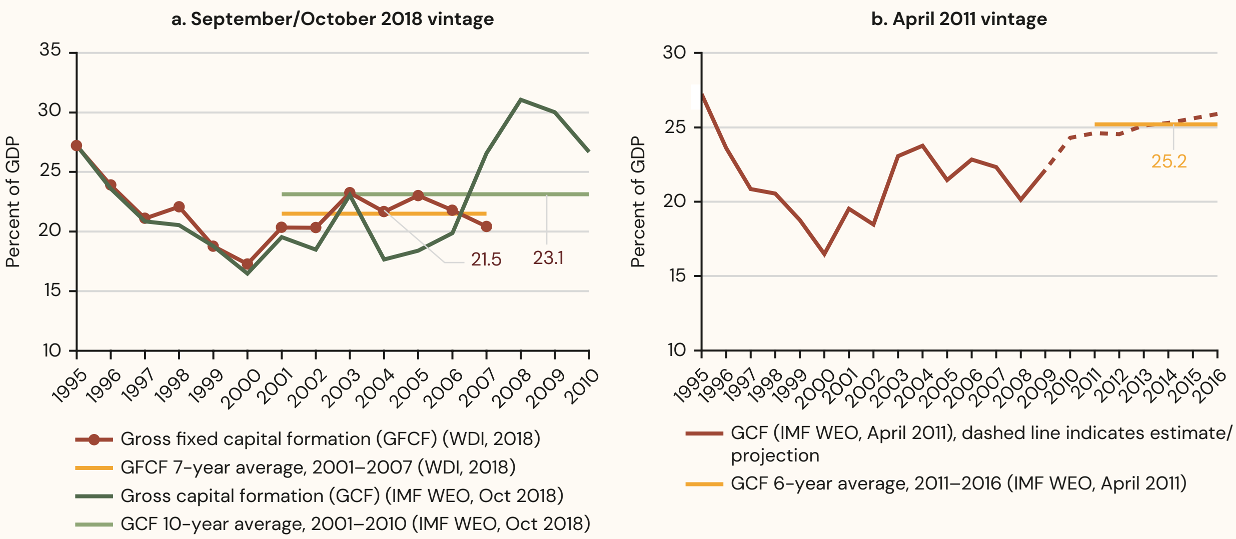
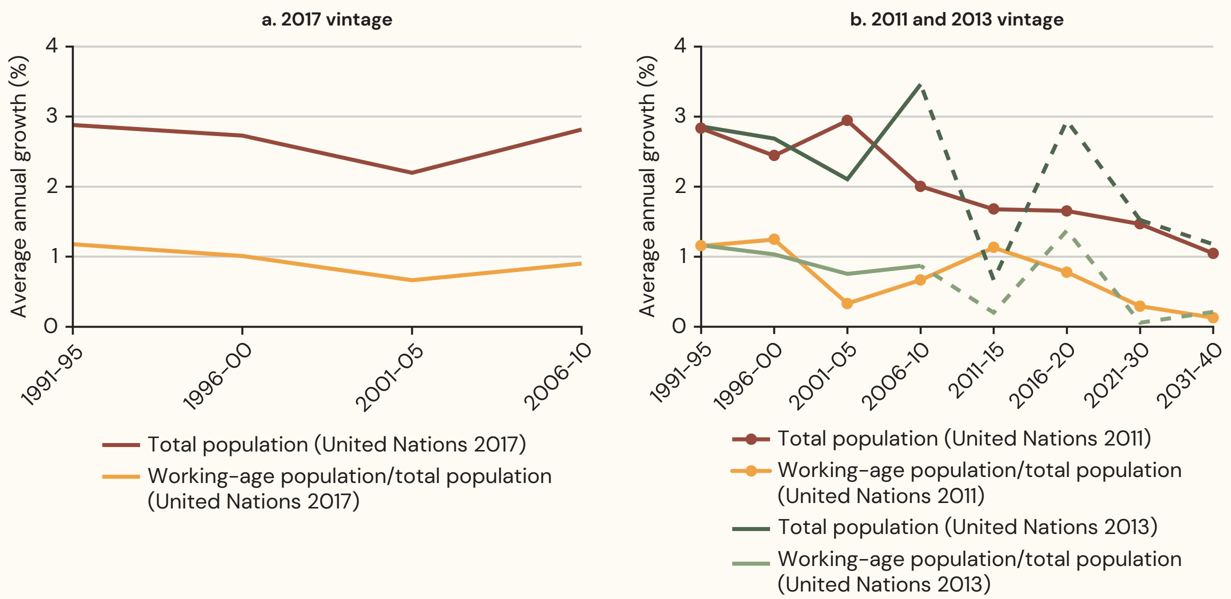
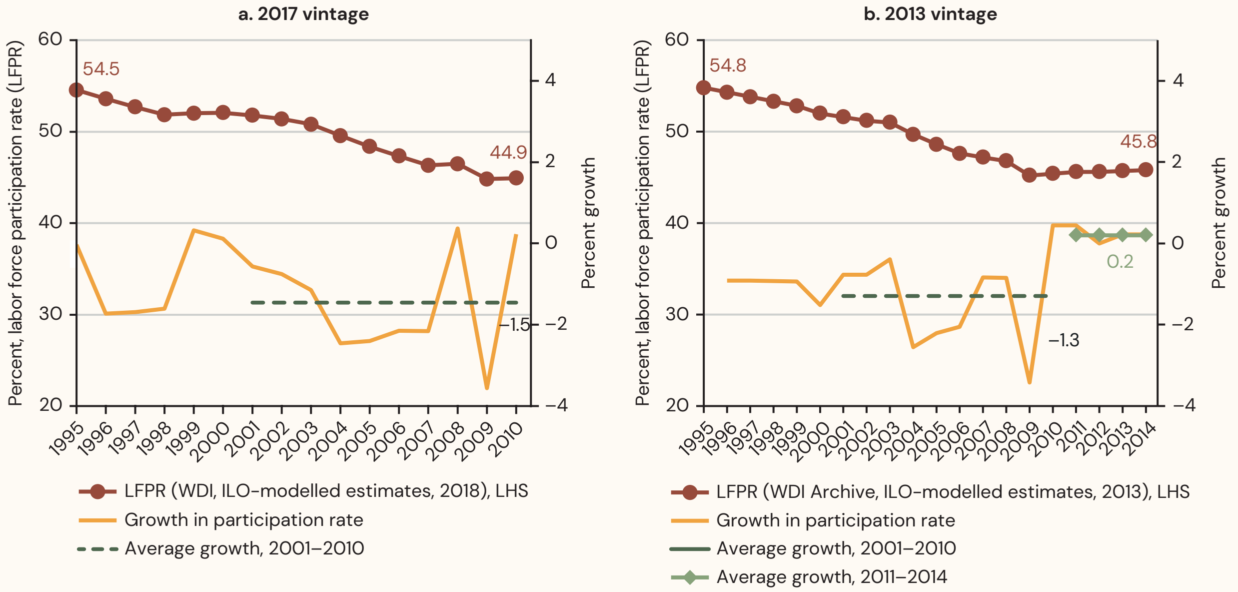


Figure 8.3: Pre-Conflict Population Growth Rate and Projection



Note: Dashed lines indicate projections for years beyond UN report dates.

Figure 8.4: Pre-Conflict Labor Force Participation Rate and Projection



except Yemen. Nasser and Mehchy (2012) note that a sizeable portion of the economically active population that went out of the labor force in the 2000s consisted of women in the agriculture sector (affected by the drought and higher fuel prices in the second half of the 2000s), and workers becoming students. Early in the conflict, the International Labour Organization (ILO)-modelled estimates suggested a stabilizing participation rate after 2010 (Figure 4(b)), though some caution needs to be exercised in taking this at face value given uncertainty surrounding the underlying data.[4]

Human capital growth in Penn World Tables (PWT) 9 (Feenstra, Inklaar, and Timmer 2015), which uses Cohen, Soto, and Leker (CSL) data (Cohen and Soto 2007; Cohen and Leker 2014) for the average years of schooling of the population ages 25 and above, averaged 1.0% for the 10 years up to 2010.[5] Figure 8.5a shows average years of schooling based on select age groups under both CSL and Barro and Lee (BL) measures. Barro and Lee (2015) projections indicate a continued rise in the average years of schooling absent conflict, for the population ages 15–64: 1.6 years over 2011–2030. Figure 8.5b shows human capital growth, based on the schooling years under CSL and BL measures. While fluctuations and differences are obvious decade to decade, there is consistency in a long-term average of approximately 1.5%.

TFP growth, averaged 1.4% over 2001–2010 based on calculations by The Conference Board (2018). Our own estimations following the methodology in Kim and Loayza (2019) also suggest an average growth rate of 1.4% for the same period.[6] See figure 8.6.

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[4] ILO-modelled estimates are based on projections for GDP-related variables and population structure. The 2013 estimates draw on IMF WEO April 2013 and United Nations (2013). However, the IMF stopped publishing projections for Syria effective 2012, and ILO uses the regional median growth to extrapolate GDP growth for Syria.

[5] See the documentation, "Human Capital in PWT 9.0." (https://www.rug.nl/ggdc/docs/human_capital_in_pwt_90.pdf).

[6] TFP is measured by growth accounting. Syria data for output, physical capital, human capital, and employed persons are from PWT 9. Labor share is proxied by the average for four relatively conflict-free middle-income MENA economies (Djibouti, Jordan, Morocco, and Tunisia).

Figure 8.5: Pre-Conflict Human Capital and Projection

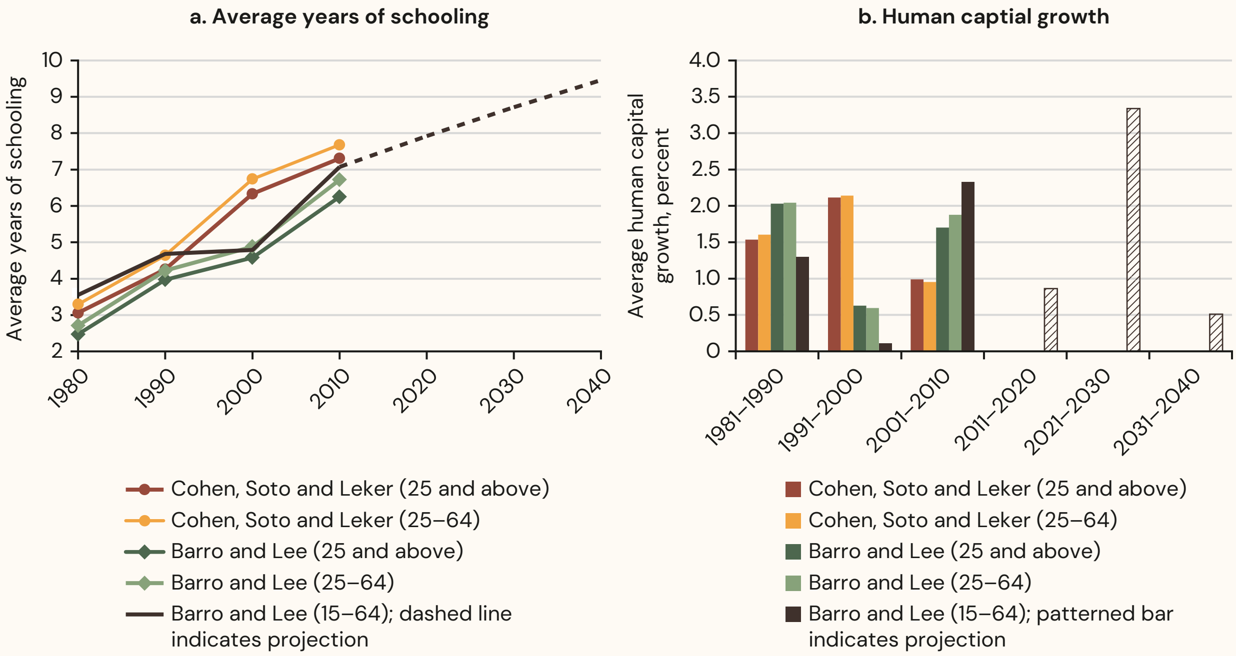
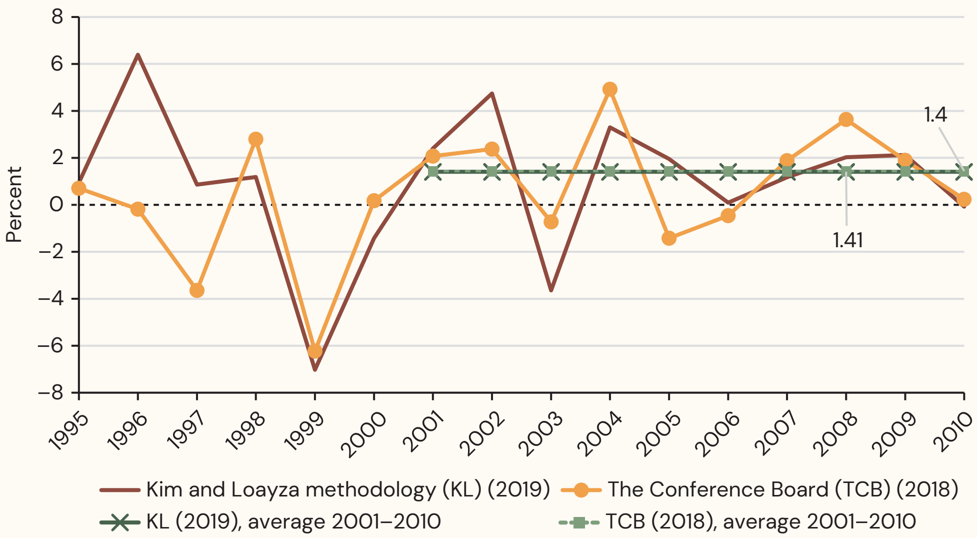


Figure 8.6: Pre-Conflict Total Factor Productivity (TFP) Growth



2.2 Simulation of what would have happened in the absence of conflict

Table 8.1 details the baseline calibration of the LTGM-PC, comprising key parameters and initial conditions (panels a and b), and the central projected paths of key growth drivers over 2011–2030 (panel c). Key parameters and initial conditions either take their 2010 values or are calibrated. In particular, we calibrate the initial capital-to-output ratio, K_0/Y_0 at 2.560 assuming steady-state properties and based on 30-year averages of the investment-to-GDP share (22.0%), GDP growth (4.1%), and aggregate depreciation rate (4.5% in PWT 8.1). Taking this approach at least provides us with some basis of setting an initial K_0/Y_0 that is in between the PWT values for 2010 (2.384 based on PWT 9 and 2.632 based on PWT 8.1), especially

Table 8.1: No-Conflict Baseline Simulation— Values for Parameters, Initial Conditions, and Projected Variables

Parameter/variable*	Note	Input value		
		2010/ Calibrated	Average, pre-conflict	Average, 2011–2030
A. Constant parameters				
Labor share β	*(1)*	0.520		
Aggregate capital depreciation rate δ	*(2)*	0.048		
Public capital depreciation rate δ^G	*(2)*	0.031		
Private capital depreciation rate δ^P	*(3)*	0.062		
B. Initial conditions				
Initial capital-to-output ratio K_0/Y_0	*(4)*	2.560		
Public capital share of total capital K^G/K	*(5)*	0.450		
Initial public capital-to-output ratio $K_0^G\ /\ Y_0$	*(6)*	1.152		
Initial private capital-to-output ratio $K_0^P\ /\ Y_0$	*(6)*	1.408		
C. Projected variables, central path (2010/11–30)				
Investment-to-output ratio I/Y	*(7)*		0.215	
Public investment-to-output ratio I^G/Y	*(7)*		0.086	
Private investment-to-output ratio I^P/Y	*(7)*		0.129	
Human capital growth g_h	*(8)*		0.010	
TFP growth g_A	*(9)*		0.014	
Population growth rate g_N	*(10)*			0.016
Working-age-to-population share, growth g_ω	*(10)*			0.006
Labor force participation rate, growth g_ϱ	*(11)*		0.000	

Note: *Multiply by 100 to obtain parameter/variable values in percent share or growth terms (%).
(1) PWT 9. Average of 2010 values for Djibouti, Jordan, Morocco, and Tunisia.
(2) δ is PWT 8.1 data for Syria. δ^G is the PWT 9 depreciation rate for nonresidential structures.
(3) δ^P is derived as the residual from a weighted average calculation of δ based on δ^G and K^G/K.
(4) Calibrated based on long-term averages of I/Y , GDP growth and δ In steady-state, output grows at the same rate as capital stock, which allows us to write, $K/Y = I/Y/(g_Y + \delta)$ where g_Y is average output growth. We use: 30-year averages of I/Y (22%), g_Y (4.1%), and δ (4.5%).
(5) Calibrated based on average shares for lower-middle-income countries and oil-based economies (fuel exports/total merchandise exports ≥ 30%). K^G/K data is from the IMF FAD Investment and Capital Stock Database 2017.
(6) $K_0^G\ /\ Y_0$ and $K_0^P\ /\ Y_0$ are derived by applying K^G/K to K_0/Y_0.
(7) Gross fixed capital formation (% of GDP), average for 2001–2007 from WDI. Public investment share assumed at 40% based on World Bank (2017) and IMF (2010).
(8) PWT 9. Average growth rate, 2001–2010.
(9) Authors' estimate. Average growth rate, 2001–2010.
(10) United Nations (2011).
(11) Based on the stabilizing participation rate observed in the 2013 ILO-modelled estimates.

since the PWT 9 value puts Syria on the border of the 75th percentile of lowest capital-to-output, K/Y ratios, and is below the respective averages of lower-middle-income countries and low-income countries, as well as MENA countries.

We also consider lower and upper estimates based on adjustments to some of the central projections for growth drivers— table 8.2 displays these calibrations. Notes to tables 8.1 and 8.2 explain the calibrations.

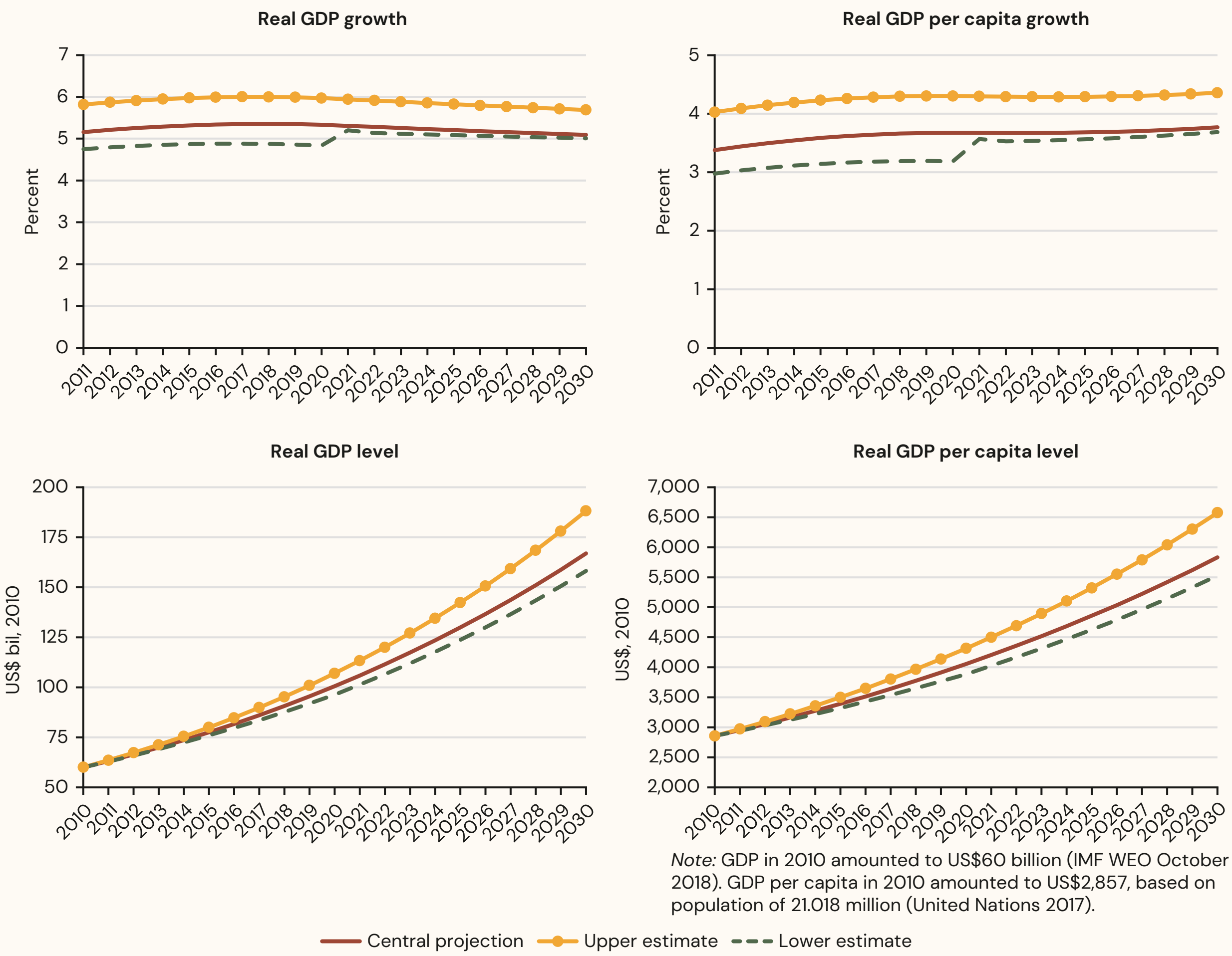
Figure 8.7 shows the trajectory for the level and growth of GDP in Syria based on the calibrations. The baseline assumptions are consistent with a long-term GDP growth average of close to 5.0%.

Table 8.2: No-Conflict Simulation—Upper and Lower Estimates for Projected Variables

Variable	Note	Input value
Lower estimate on projected variables (average, 2011–2030)		
Labor force participation rate, growth g_ϱ	(1)	–0.003
Upper estimate on projected variables (average, 2010/11–2030)		
Investment-to-output ratio I/Y	(2)	0.235
Public investment-to-output ratio I^G/Y	(2)	0.094
Private investment-to-output ratio I^P/Y	(2)	0.141
Human capital growth g_h	(3)	0.015

Note: *Multiply by 100 to obtain parameter/variable values in percent share or growth terms (%).
(1) May 2018 ILO-modelled estimates.
(2) I/Y is based on IMF data suggesting higher GCF (% of GDP) after 2010. Public investment share of total investment unchanged at 40%.
(3) Long-term average. See section 2.1.

Figure 8.7: No-Conflict Simulation for GDP in Syria



Note: GDP in 2010 amounted to US$60 billion (IMF WEO October 2018). GDP per capita in 2010 amounted to US$2,857, based on population of 21.018 million (United Nations 2017).

Average real GDP growth of 5.3% over 2011–2018 in the absence of conflict would have led to real GDP rising from US$60 billion in 2010 to US$91 billion, and real GDP per capita rising from US$2,857 to US$3,774 by 2018 (upper estimate: GDP of US$95.3 billion and GDP per capita of US$3,997 in 2018; lower estimate: GDP of US$87.6 billion and GDP per capita of US$3,649 in 2018).

3. Impact from Conflict

This section provides a simulation of how the different growth drivers account for the loss in GDP growth over 2011–2018. The purpose of this simulation is to provide an up-to-date and holistic analysis of what happened to GDP potential based on its underlying drivers. Such an analysis complements other work done, for example, by the UN-ESCWA and the World Bank, which have documented overall GDP loss by sector and expenditure components. Furthermore, the analysis in this section is a necessary step toward establishing, as best as possible, the initial conditions post-conflict, an important precursor to simulations for the reconstruction period.

3.1 How were the drivers of growth affected by the conflict?

3.1.1 Physical capital stock and investment

We use estimates of physical capital stock damage by the UN-ESCWA, which appear to be the most comprehensive and up-to-date data so far. ESCWA (2018) puts the destruction of capital across various economic sectors, including public and private capital, at US$119.7 billion by the end of 2017. As pockets of fighting continued in Syria in 2018, we build in further damages of US$7 billion to total US$126.7 billion in 2018 (more than five times the GDP level in 2018). See appendix 2 for details.

World Bank (2017) estimates a decline in private investment as a share of GDP (I^P/Y) from 12% in 2010 to 4% in 2015, and for the public investment-to-GDP ratio (I^G/Y), a decline from 9% in 2010 to 1% in 2015. ESCWA (2018) sees a smaller decline, from 12% to 9% for private investment as a share of GDP (averages for 2006–2010 and 2011–2016, respectively) and from 10% to 7% for public investment as a share of GDP. In our simulations, we use the World Bank estimates for our central projections, assuming I^P/Y and I^G/Y remain stable at 4% and 1%, respectively, over 2016–2018. We then consider the ESCWA estimates as an upper estimate to our projections.

A deterioration in the efficiency of public investment is a likely concern. No Syria-specific value of the Infrastructure Efficiency Index (IEI) (Devadas and Pennings 2019) is available. As a proxy for Syria's pre-conflict efficiency of new public investment, we use the lower-middle-income (LMI) average of 0.734 and build in a decline to the low-income (LI) group average of 0.570 by 2017 (at which point the World Bank's income classification of Syria switches from LMI to LI).

3.1.2 Demographics and the labor force

United Nations (2017) indicates negative average annual population growth of –1.7% over 2011–2018, (from 21.0 million people in 2010 to 18.3 million in 2018), and for the working-age-to-population share, negative average annual growth of –0.09%. From mid-2010 to mid-2020, estimated deaths are higher at 1,036,445 (5.6% of the average population over 2010–2020) compared with 657,131 (3.5% of the average population over 2000–2010) the previous decade. Net emigration is tallied at 5,397,896 (25% of the population in 2010). The latter considers refugee numbers from the UN Refugee Agency (UNHCR) populations of concern data up to March 2017.

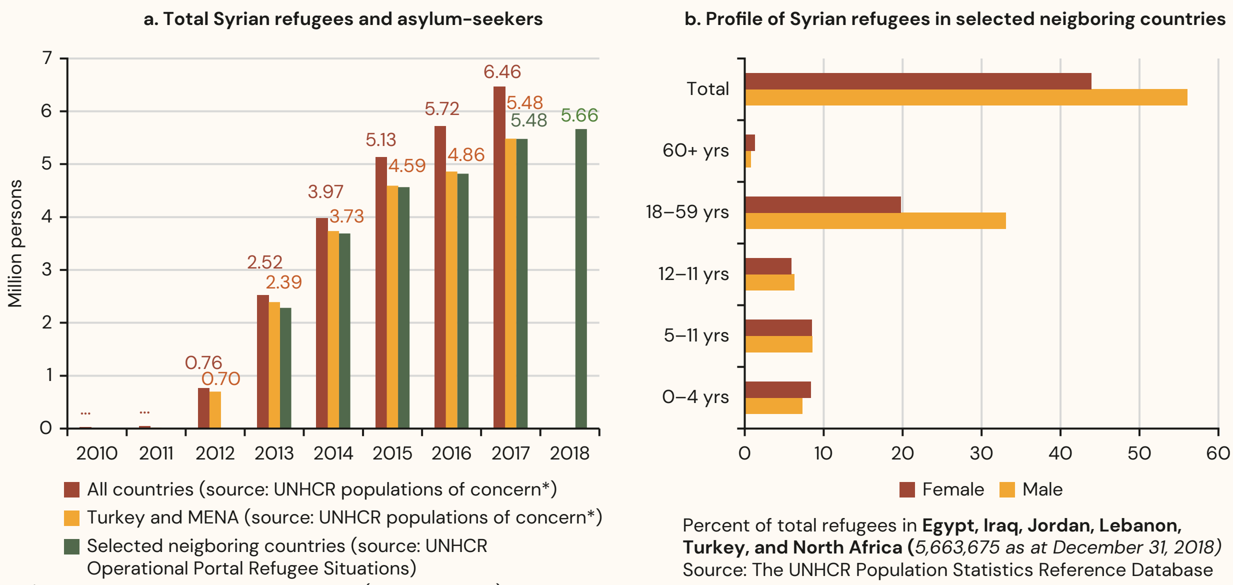
The above numbers might understate fatalities and migrants. The cumulative number of fatalities from the war is hard to ascertain. SOHR data put Syrian fatalities at 494,892 over March 2011 – December 10, 2018,[7] higher than what is suggested by UN population statistics. The UNHCR populations of concern data show that compared to 2016, total registered Syrian refugees and asylum-seekers increased in 2017 by 746,811 (figure 8.8a). While the equivalent 2018 data are not available, from data on refugees in selected neighboring countries, we note that when compared to 2017, refugees had increased by 184,398 to 5,663,675 in 2018, around one-third of the remaining population in Syria in 2018 (patterned bars in figure 8.8a). Based on this, the UN population statistics may be understating refugees by about 900,000. However, if we discount the 1 million refugees born in exile supposedly included in the UNCHR data, then the underrepresentation of population "loss" in the UN population statistics due to the use of outdated UNHCR data disappears.

Of greater concern then is that the UN population statistics likely do not include non-registered Syrians in neighboring countries, for which estimates vary but tend to go up to more than a million; see, for instance, Vignal (2018) and World Bank (2019). UNDP and UNHCR (2019) put the difference between estimated total Syrians and registered Syrian refugees at about 1.6 million in December 2018. The difference is wholly accounted for by Egypt, Jordan, and Lebanon.

Consequently, as a lower estimate to population growth, we calculate an added decline in the Syrian population of 1.8 million, building in additional conflict deaths of 200,000 and unregistered Syrian migrants of 1.6 million. This would reduce the 2018 population from 18.3 million to 16.5 million giving a negative average growth of –3.0% over 2011–2018.

May 2018 ILO-modelled estimates show the overall LFPR at 43.0% in 2018, giving an average negative growth of –0.5% over 2011–2018. World Bank (2019) shows 2017 LFPRs for men and women above 15 years of age at 79.1% and 11.9%, respectively, versus 73.0% and 13.0% in 2010. We use the ILO estimates in our central projection, and for a possible upper estimate, consider an increment in the LFPR by 2018 based on the changes in participation rates reported in World Bank (2019).

Figure 8.8: **UNHCR Registered Syrian Refugees and Asylum-Seekers**



*Comprises refugees, asylum-seekers (pending cases), and others of concern.

Percent of total refugees in **Egypt, Iraq, Jordan, Lebanon, Turkey, and North Africa (***5,663,675 as at December 31, 2018)*
Source: The UNHCR Population Statistics Reference Database and the UNHCR Operational Portal Refugee Situations—Syria Regional Refugee Response. (https://data2.unhcr.org/en/situations/syria).

[7] http://www.syriahr.com/en/?p=108723.

3.1.3 Human capital

Human capital would have been affected by (i) the interruption of schooling of the younger population, who represent future entrants into the labor force; and (ii) migration and fatalities which alter the distribution of years of schooling among the remaining population.

According to the Syrian Center for Policy Research (SCPR 2016), almost one-half (45.2%) of all basic education school-age children residing within the country were not attending school by 2014–2015. They estimate a decline of 1.5 in the average years of schooling for the population ages 15 and above, based on these non-attendance rates, from 6.8 in 2010 to 5.3 years in 2015.

We provide alternative calculations to assess the impact from the interruption of schooling as well as migration and fatalities on the national average of years of schooling. To do this, we use forward extrapolations, with the following assumptions:[8]

- for age groups, $\alpha = 3{:}25-29$ to $\alpha = 10{:}60-64$, the educational attainment (average schooling years), *s*, of gender *g* (either men, *m* or women, *f*) in age group, α, at time, *t*, is the same as that of the age group five years younger at time, $t-5$, as we assume these groups have completed their education, i.e.,

$$s_{g,t}^{a} = s_{g,t-5}^{a-1} \tag{1}$$

- for age groups, $\alpha = 1$: 15–19 and $\alpha = 2$:20–24,who are still in school, we use the attainment in $t-5$ for the same group α, adjusted to account for changes in enrollment ratios, $\Delta enroll_{g,j,t}^{a}$[9] for age group α in education level *j* (primary, secondary, and tertiary; incomplete and complete) during the transition period from $t-5$ to *t*, i.e.

$$s_{g,t}^{a} = s_{g,t-5}^{a} + \sum_{j} \Delta enroll_{g,j,t}^{a} \, Dur_{j,t-5}^{a} \tag{2}$$

Dur is the corresponding duration system of education level *j* , which we assume to be unchanged.

Average total years of schooling for each age group s_t^a is then a composite of the respective average years of schooling of men (*m*) and women (*f*) in that group:

$$s_t^a = s_{f,t}^a \times \frac{Pop_{f,t}^a}{Pop_t^a} + s_{m,t}^a \times \frac{Pop_{m,t}^a}{Pop_t^a} \tag{3}$$

where Pop_t^a is population in age group α at time *t*.

Finally, we derive average total years of schooling for the population ages 15–64:

$$s_t = \sum_{a=1}^{10} s_t^a \times \frac{Pop_t^a}{Pop_t^{(15-64)}} \tag{4}$$

where $Pop_t^{(15-64)}$ is the total population for ages 15–64 at time *t*.

Primary and secondary net enrollment rates stood at 93% and 67%, respectively, in 2010 (UNESCO Institute for Statistics [UIS]).[10] Last available data from the UIS indicates that these rates declined to 63% and 46%, respectively, in 2013, with the secondary enrollment rate stable at 45% in 2018 (UNICEF 2018). For our projection of average years of schooling for the still-in-school groups using equation (2), we let the 2010 primary and secondary enrollment rates decline to 75% and 45%, respectively, by 2015 for both girls

[8] The nomenclature follows Barro and Lee (2013, 2015).

[9] We base the enrollment adjustment factor formula on Barro and Lee (2013) (their table A.2).

[10] http://uis.unesco.org/country/SY.

and boys, keeping them steady thereafter.[11] Regarding tertiary education, the UIS data rather surprisingly suggest an increment of about 10 percentage points in the gross enrollment rate during the conflict from 26% in 2010.[12] We build in this increment over 2010–2015, applying the same enrollment rate for men and women, and keep it unchanged thereafter. Primary school duration is assumed to be 6 years (6–11 years), secondary school, 6 years (12–17 years), and university 4 years (18-21 years). Appendix 3 provides further details on how we arrive at the average years of schooling in 2018.

Our approach constrains changes to the national average of schooling years to arise from shifts in the distribution of the total population by age and gender, and in enrollment ratios. Because we use past composite values of average years of schooling, we do not consider changes in completion rates. This approach also does not consider other types of heterogeneity in educational attainment, for instance, that depend on the socioeconomic status or geographical origination of migrants and conflict victims. Verme et al. (2016) find that Syrian refugees in Jordan and Lebanon in fact tend to have slightly lower levels of educational attainment than pre-conflict Syrians.

To obtain human capital growth, we continue to use the same method and returns to education as in PWT 9. For the central projection using UN population statistics, we find that average years of schooling would have declined by 1.467 years for the population ages 15–64 with human capital contracting by an annual average growth of –2.59% over 2011–2015 and –0.56% over 2016–2018, respectively. With the additional decline of 1.8 million in the Syrian population for the lower estimate, average years of schooling declines only marginally more— by 1.499 years.

3.1.4 TFP

The key element that feeds into the model of TFP growth in Kim and Loayza (2019) is an overall index of TFP determinants, the determinants being education, infrastructure, innovation, institutions, and market efficiency. The composite index stood at 30.33 for Syria in 2010 on a scale between 1 and 100. We estimate the trajectory of this index over 2011–2018 by calibrating its subcomponents.

For the education index, we calculate a decline that is proportionate to our estimates of the fall in average years of schooling of the working-age population. For the infrastructure index, we build in a decline that is proportionate to the relative total light in Syria over time estimated by Li et al. (2017). For the institutions index, the estimation is based on the Worldwide Governance Indicators (WGI) across six dimensions (Kaufmann, Kraay, and Mastruzzi 2010). For the innovation and market efficiency indices, we assume that these evolve proportionately to a weighted average of the indices for infrastructure and institutions.

This gives an overall TFP determinant index of 15.98 in 2018, almost one-half the 2010 level. The associated average annual TFP growth over 2011–2018 is –1.6%. Further details are provided in appendix 4.

3.2 Simulation of the impact from the conflict

Table 8.3 details the baseline calibrations of conditions during the conflict years 2011–2018, following the discussion in section 3.1. Regarding the public and private capital to output ratios, K^G/Y and K^P/Y , the simulated ratios inclusive of damage in table 8.3, panel b, use calculations described below to reflect the damage to capital stocks:

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[11] We use a simple average calculation to obtain the 2015 primary enrollment rate based on a net enrollment rate for school-age children of 60% (UNICEF 2016) and secondary enrollment rate of 45%. The net enrollment rate for school-age children appears to have been relatively stable after 2015, amounting to 61% in 2018 (World Bank 2019).

[12] Milton (2019) discusses how Syria's higher education system survived quantity wise, despite general expectations that higher education suffers relatively more during conflict, but that quality had been eroded and political control over campuses increased.

Table 8.3: Simulation of Syria's Conflict Years (2011–2018)

Parameter/variable	Note	2010	Average 2011–2018	2018
A. Constant parameters				
Labor share β	*(1)*		0.520	
Aggregate capital depreciation rate δ	*(1)*		0.048	
Public capital depreciation rate δ^G	*(1)*		0.031	
Private capital depreciation rate δ^P	*(1)*		0.062	
B. Capital-to-output (K/Y) ratios				
Initial public capital-to-output ratio K_0^G / Y_0	*(1)*	1.152		
Simulated K_c^G / Y (with damage)	*(2)*		1.141	1.029
Initial private capital-to-output ratio K_0^P / Y_0	*(1)*	1.408		
Simulated K_c^P / Y (with damage)	*(2)*		1.144	0.708
C. Projected variables, central path (2011–2018)				
Public investment-to-output ratio I^G/Y	*(3)*	0.090	0.025	0.010
Private investment-to-output ratio I^P/Y	*(3)*	0.120	0.064	0.040
Efficiency of new public investment q^N	*(4)*	0.734	0.632	0.570
Human capital growth g_h	*(5)*		–0.018	–0.006
TFP growth g_A	*(6)*		–0.016	–0.022
Population growth rate g_N	*(7)*		–0.017	0.001
Working-age-to-population share, growth g_ω	*(7)*		–0.001	0.011
Labor force participation rate, growth, g_Ω	*(8)*		–0.005	–0.008

Note: *Multiply by 100 to obtain parameter/variable values in percent share or growth terms (%).
(1) Unchanged from Table 1.
(2) See Sections 3.1.1 and 3.2.
(3) Based on World Bank (2017).
(4) Average IEI for LMI countries for 2010 which is assumed to gradually decline to the average IEI for LI countries by 2017.
(5) See Section 3.1.3. Since the fall in enrollment rates and the exodus of Syrians occurs noticeably from 2013, we keep the human capital unchanged from 2010 to 2012, such that the contraction mainly occurs over 2013–2015: average growth of –4.28% (average growth, 2016–2018: 0.56%).
(6) See section 3.1.4.
(7) Based on United Nations (2017).
(8) May 2018 ILO-modelled estimates.

- Each period's initial K^G/Y and K^P/Y are reduced by lowering K^j (for $j = G,P$) by the amount of the monetary value of physical damage (with Y held constant). Damage during a period (year) affects capital and initial capital-to-output ratios for the next period.

  Initial conflict capital-to-output ratios, $\dfrac{K^j_{c,0}}{Y_0} = \dfrac{K^j_{c,2011}}{Y_{2011}}$

  where $K^j_{c,2011}$ is capital adjusted for damage, D^j_{2011}.

  Then, $\dfrac{K^j_{c,2011}}{Y_{2011}} = \dfrac{K^j_{2010}}{Y_{2010}} \times \dfrac{1+g_{k^j_c,\,2011}}{1+g_{y,\,2011}}$

  where K^j_{2010} is based on $\dfrac{K^j_{2010}}{Y_{2010}}$ of 1.152 and 1.408, respectively, for public and private capital, and Y_{2010} = US$60.043 billion;

growth in adjusted capital per worker, $$1+g_{k_e^j,\,2011}=\frac{\left(1-\delta^j\right)\left(1-d_{2011}^j\right)+\dfrac{I_{2010}^j/Y_{2010}}{K_{2010}^j/Y_{2010}}}{\left(1+g_{\varrho,\,2011}\right)\left(1+g_{\omega,2011}\right)\left(1+g_{N,2011}\right)} \quad (5)$$

where $d_{2011}^j=\frac{D_{2011}^j}{K_{2010}^j}$, the proportion of capital damaged in 2011.

and growth in output per worker,

$$1+g_{y,2011}=[(1+\Gamma_{2011})^{(1-\zeta)\phi}]\left(1+g_{A,\,2011}\right)\left(1+g_{\theta,\,2011}\right)^{\phi}\left(1+g_{k_e^G,2011}\right)^{\phi}\left(1+g_{k_e^P,2011}\right)^{1-\beta-\zeta\phi}\left(1+g_{h,2011}\right)^{\beta}$$

$$\text{with } 1+\Gamma_{2011}=(1+g_{\varrho,2011})(1+g_{\omega,2011})(1+g_{N,2011}) \quad (6)$$

- The process is repeated for periods 2012–2018. Damages to K_t^j are apportioned across the conflict period based on the estimates discussed in section 3.1.1. Damages are apportioned between public and private capital based on their relative cumulative shares as at end 2015, made available by ESCWA. We assume the same shares for each time *t* (that is, 40% of damages are attributable to public capital, 60% to private capital).

Under the central projection, both K^G/Y and K^P/Y are lower in 2018 (1.029 and 0.708, respectively) compared with 2010 (1.152 and 1.408, respectively), but more so in the latter case, since the damage value for private capital is higher. In the lower and upper estimate scenarios for selected growth drivers (table 8.4), the K/Y ratios in 2018 are slightly higher than in the central projection but remain lower than the 2010 levels.

Figure 9a– 9b shows the outcomes of simulations for GDP level and growth over the conflict years given the calibrations in tables 8.3 and 8.4. Our simulations of the impact from the conflict across the three scenarios (central, lower, and upper estimate projections) from 2011–2018 indicate that the depletion of factors of production alone may account for about 87% of the negative GDP growth on average, and further, that about 64% of the average negative growth is due to physical capital destruction. Demographics and labor account for about 15%, human capital 7%, and TFP 13% of GDP growth on average over the conflict years.

The decrease in physical capital reflects the compounded effects of large outright damages, low net investment rate, and a falling output base (which is adversely affected by all growth drivers). The prominent effective losses due to physical capital destruction are worsened by the lack of investment. This echoes the observation by World Bank (2017) that capital destruction itself might have relatively subdued effects in a well-functioning economy, as in the aftermath of a natural disaster; but in the case of conflicts, the fall in investments due to disruptions in economic organization reinforces the adverse effects from physical capital damages. Having said that, our estimate of physical capital decrease is greater than the estimate in World Bank (2017) because of methodological reasons: we take into account the monetary value of physical capital destroyed, as reported by ESCWA (2018), as well as depreciation and gross investment, directly in the calculation of the capital stock; while World Bank (2017) assumes that the resulting capital stock keeps the same proportion with respect to the initial capital stock as the stock of housing does. Consequently, World Bank (2017) finds that the impact of capital destruction on GDP growth is not as immense. They find that in a scenario with only capital damage, GDP only decreased by –3.5% from the pre-conflict GDP level in the sixth year of conflict, compared to the –65.2% decrease in the scenario where all shocks

Table 8.4: Simulation of Syria's Conflict Years (2011–2018) —Lower and Upper Estimates and Impact on Capital-to-Output Ratios

Variable	Note	Average 2011–2018	2018
A. Lower estimate			
Population growth g_N	(1)	–0.030	0.000
Human capital growth g_h	(2)	–0.019	–0.006
Capital-to-Output (K/Y) Ratios (with Damage)			
Simulated K_c^G / Y		1.180	1.091
Simulated K_c^P / Y		1.175	0.737
B. Upper estimate			
Public investment-to-output ratio I^G/Y	(3)	0.070	0.070
Private investment-to-output ratio I^P/Y	(3)	0.090	0.090
Labor force participation rate, growth, g_Q	(4)	0.007	0.006
Capital-to-output (K/Y) ratios (with damage)			
Simulated K_c^G / Y		1.133	1.127
Simulated K_c^P / Y		1.139	0.784

Note: *Multiply by 100 to obtain parameter/variable values in percentage share or growth terms (%).

(1) See Section 2.2.

(2) See Section 3.1.3. As in the central projection, we keep the human capital index unchanged from 2010 to 2012, such that the contraction mainly occurs over 2013–2015: average growth of –4.37% (average growth, 2016–2018: 0.57%).

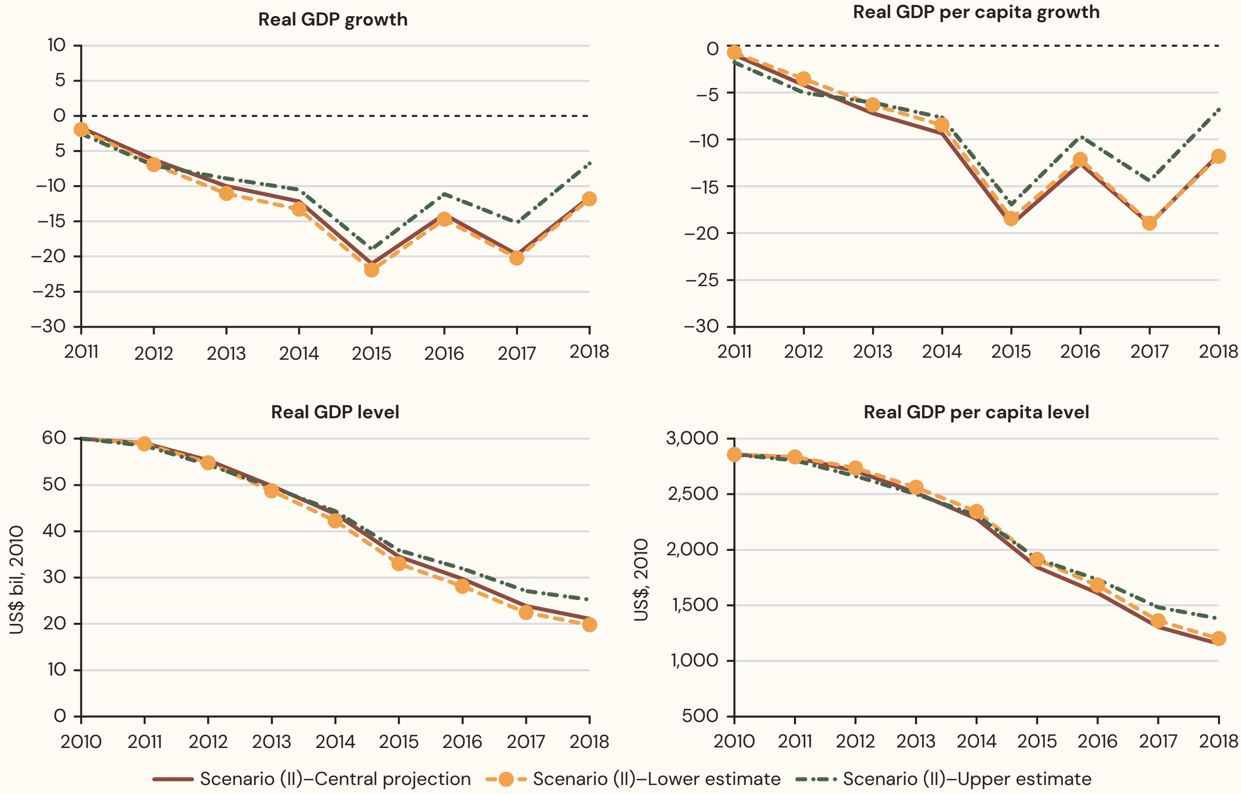
(3) Based on ESCWA (2018).

(4) Based on World Bank (2019).

including casualty and economic disorganization were included. The impact for growth when there is only casualty is comparable to the capital stock damage case at –3.9%. Economic disorganization has the biggest impact, with GDP decreasing by –59.8% from the pre-conflict level on the sixth year of conflict. Overall, notwithstanding the differences in the relative importance of factors, the cumulative GDP loss is similar at US$226 billion over 2011–2016 (in 2010 prices), almost four times the GDP level in 2010.

Comparisons against the no-conflict scenario suggest a cumulative loss in GDP potential of between US$289 and US$300 billion over 2011–2018 (figure 10a). Our estimates point to a continued loss in 2017–2018 because of the damage to physical capital and negative TFP growth. This varies somewhat from ESCWA (2018) and others like Devarajan and Mottaghi (2017), Gobat and Kostial (2016), and World Bank (2017), all of which point to a trough in *actual* GDP contraction around 2012–2013. ESCWA (2018) estimates average GDP growth of –10% over 2011–2017, with growth turning positive in 2017. ESCWA also projects a GDP level of US$27 billion in 2017 against a no-conflict counterfactual of US$86 billion. Our estimates seem to mimic these results, pointing to a GDP growth of –12% on average over 2011–2018 (across all three scenarios under the conflict simulation), with an average GDP level of US$22 billion in 2018 (against a no-conflict scenario of US$91 billion). Per capita GDP is estimated at US$1,154 in 2018 under the central projection (upper estimate: US$1,381; lower estimate: US$1,200).

Figure 8.9a: Conflict Years Calibration for GDP in Syria



Note: GDP in 2010 amounted to US$60 billion (IMF WEO October 2018). GDP per capita in 2010 amounted to US$2,857, based on population of 21.018 million (United Nations 2017).

Figure 8.9b: Average Impact of Different Growth Drivers on GDP during the Conflict (across Central, Lower and Upper Estimate Projections)

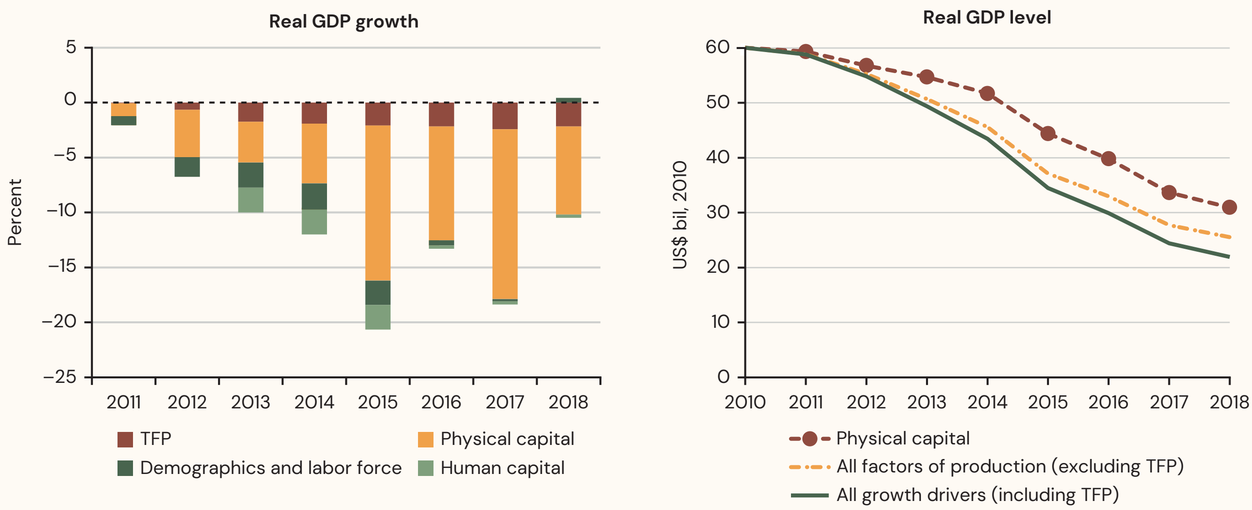
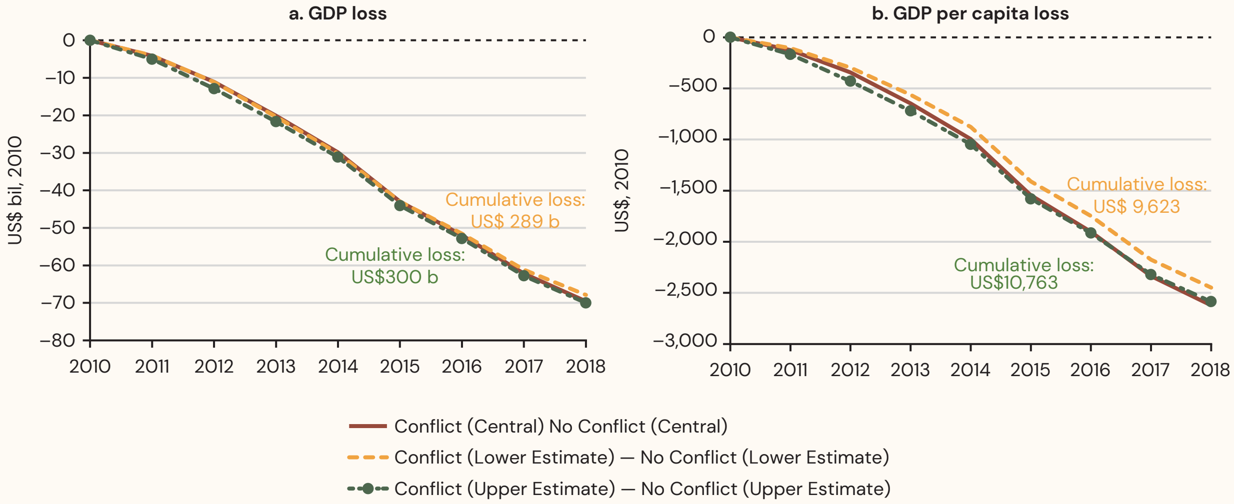


Figure 8.10: GDP Loss Based on the Conflict Simulation Compared to the Counterfactual of No Conflict



4. Growth Scenarios Post-Conflict

This section discusses potential growth scenarios for Syria in the aftermath of war, exploring how long it would take for Syria to reach its pre-conflict level of development under various assumptions for the growth drivers.

Experiences of other countries in the Middle East suggest that longer lasting conflicts would entail longer recovery periods. Sab (2014) notes that it took Lebanon 20 years to reach its pre-war GDP level (after the Lebanon Civil War from April 13, 1975–October 13, 1990), Kuwait, seven years (Gulf War from August 2, 1990–February 28, 1991), and Iraq, one year only (2003 invasion of Iraq from March 19–May 1, 2003). Lebanon lost 70% of its GDP level, Kuwait 55%, and Iraq 35% during their respective wars. Gobat and Kostial (2016) note that under the hypothetical assumption of reconstruction starting in 2018 and the Syrian economy growing at about 4.5%, it would take the country about 20 years to reach its pre-conflict real GDP level. ESCWA (2018) puts Syria's real GDP at about US$ billion in 2017— some 55% below the 2010 level and close to the level in the early 1990s. Our central projection of Syria's potential GDP level in section 3, at US$21.2 billion in 2018, is 65% below the GDP level in 2010, close to the loss experienced by Lebanon.

To analyze the growth outlook in Syria, we consider a voluntary mobility case within which our projections for the growth drivers are guided by three plausible political settlement/security outcomes (baseline/moderate, optimistic, and pessimistic). These settings are associated with varying levels of reconstruction assistance, which influence the voluntary mobility of refugees residing in neighboring countries. The amount of reconstruction funds directly affects public and private investment, while refugee returns affect the labor force size. We also build in variation in human capital growth based on different assumptions for enrollment rates and vary the projections for TFP growth across the three scenarios.

We also look at a second broad case of forced repatriation of refugees. Forced repatriation would contravene UN principles that care for the safety and welfare of refugees,[13] but it may be instigated by local and international voices eager for a quick resolution of the refugee issue.[14] Under a forced repatriation scenario, all refugees in neighboring countries are assumed to return to Syria, regardless of the type of political settlement and associated reconstruction amounts. Therefore, in this case, refugee returns are assumed to be disconnected from the size of the reconstruction program. We thus have six scenarios in total— three for each of the two different broad cases of voluntary mobility and forced repatriation, respectively. These are summarized in table 8.5. We discuss the projections for the growth drivers in section 4.1 and present the resulting simulations for Syria's growth over the next 30 years in section 4.2.

Table 8.5: Key Factors in the Post-Conflict Scenarios for Growth Drivers

Broad case	Factor	Baseline (moderate)	High (optimistic)	Low (pessimistic)
Voluntary mobility OR forced repatriation	Security	Partial political settlement with strong guarantees for micro-security and property rights.	Robust political settlement.	Political settlement largely reflects de facto balance of power, with limited guarantees for micro-security and property rights.
	Reconstruction program	US$140 billion (average of the high and low scenarios), spread evenly over a 20-year period.	Large. US$250 billion to meet UN-estimated reconstruction bill, spread evenly over a 20-year period.	Limited. US$30 billion, largely relying on China, Iran, and Russia, and spread evenly over a 10-year period.
Voluntary mobility	Refugee returns	Of total refugees in neighboring countries, 43% return rate based on the ratio of reconstruction funds in the first 10 years (moderate versus high scenario).	76% rate of refugee returns from neighboring countries, based on the UNHCR (2018) survey of refugees intending to return to Syria one day.	Of total refugees in neighboring countries, 18% return rate based on the ratio of reconstruction funds in the first 10 years (low versus high scenario).
Forced repatriation	Refugee returns	100% return rate, of refugees in neighboring countries.		

Note: Refugee returns follow the same time pattern (United Nations 2017) across the three scenarios, rising to peak around 2023–2024, and gradually moderating thereafter. World Bank (2019) finds that refugee mobilization tends to be lower, the lower are security and infrastructure services.

[13] The UN principle of non-refoulement, codified in Article 33 of the 1951 UN Refugee Convention, requires that "no contracting state shall expel or return a refugee in any manner whatsoever to the frontiers of territories where his life or freedom would be threatened."

[14] The limitations that the UN non-refoulement principle places on repatriation is frequently resented by states. Host countries are often impatient to see uninvited refugees leave. Countries of origin are sometimes impatient to see them return and signal the end of conflict. Moreover, donor states are eager to bring an end to the long-term refugee assistance programs that they fund.

4.1 Prospective developments in growth drivers

4.1.1 Physical investment

The reconstruction and expansion of Syria's physical capital will largely depend on the extent of foreign funds made available since its self-financing capacity is likely to be limited, especially in the near term. Equation (7), a slight variant of the saving/investment–balance of payments accounting identity, links $\frac{I_t}{Y_t}$ to the inflow of foreign funds.

$$\frac{S_t}{Y_t}=\frac{I_t}{Y_t}+\frac{CAB_t}{Y_t} \text{ where } CAB_t = TB_t + IB_t = -NCT_t - \Delta NFL_t \quad (7)$$

(*Note:* S_t = saving *excluding* net current transfers, CAB_t = current account balance *excluding* net current transfers, TB_t = trade balance, IB_t = income balance, NCT_t = net current transfers, and ΔNFT_t = change in net foreign liabilities.)

External financing may take the form of (non-debt creating) aid and grants (higher NCT_t) or direct investment and loans (higher foreign liabilities, thus increasing ΔNFT_t). If the foreign funds lead to an equivalent amount being spent on tradables (for example, the imports of capital goods), the current account will be in deficit, ceteris paribus. If the foreign funds do not lead to the purchase of tradables, the current account will be in balance, ceteris paribus; see Elbadawi, Kaltani, and Schmidt-Hebbel (2008) for a related discussion on how the utilization of aid monies affects current account balances and exchange rates. In our simulations, $\frac{CAB_t}{Y_t}=-\frac{\Delta FF_t}{Y_t}$ where $NC_t + \Delta NFL_t = \Delta FF_t$, the inflow of foreign funds. So, there is a corresponding amount being spent on tradables. This gives us equation (8). ΔFF_t varies across the three post-conflict scenarios as described in table 8.5: beginning in 2019, US$12.5 billion per year over a 20-year period under the optimistic scenario; US$7 billion per year over a 20-year period under the baseline scenario; and US$3 billion per year over a 10-year period under the pessimistic scenario. An even distribution of foreign funds over the 20-year and 10-year periods is assumed following the reasoning in the ESCWA (2017) report. On the one hand, the country's absorptive capacity of investment will progressively increase over time. On the other hand, national sources provide larger investment funding as the economy recovers. A stable provision of foreign funds alongside rising domestically funded investment is consistent with this chapter's assumed investment rates with respect to GDP, which are not excessively high in comparison to other post-conflict recovery experiences.

$$\frac{I_t}{Y_t}=\frac{S_t}{Y_t}+\frac{\Delta FF_t}{Y_t} \quad (8)$$

If we assume $\frac{I_t}{Y_t}$ of 5% (as per the central projection of our conflict simulation), and $\frac{CAB_t}{Y_t}$ of around –30%[15] at the end of the conflict, this would give us $\frac{S_t}{Y_t}$ of approximately –25%. This is about 50 percentage points below Syria's pre-conflict long-term average: 23%.[16] For the post-conflict pessimistic scenario, we calibrate the transition for Syria's $\frac{S_t}{Y_t}$ by 50 percentage points to 25%, in eight years, based on the experience

[15] This is based on the 2017 estimate of the trade balance share of GDP by ESCWA (2018).

[16] 20-year average, 1991–2010 (WEO data).

of Lebanon. Lebanon was subject to persistent political instability during its recovery. External assistance specific to its reconstruction program was limited, though it did receive large capital inflows attracted by high interest rates that enabled it to run current account deficits. For the optimistic scenario, we assume that Syria's saving ratio increases by 60 percentage points to 35% in five years, following the timeline and change experienced by Kuwait as it recovered to its pre-conflict saving-to-GDP level. Resource-rich, high-income Kuwait made a strong recovery after the sharp decline, as its oil production capacity was quickly restored amid a comprehensive economic recovery and reconstruction program (Sab 2014). For the moderate scenario, we take an average of the projections for $\frac{S_t}{Y_t}$ under the other two scenarios. See appendix 5 for further details.

Of projected $\frac{I_t}{Y_t}$, we continue to assume a public investment share of 40%. This is consistent with the estimated relative shares of destruction between public and private capital. We keep new public investment efficiency unchanged at 0.570 under the pessimistic scenario and assume a rise from 0.570 to 0.734 by 2038 under the baseline. For the optimistic scenario, we assume a rise to the average IEI for the upper-middle-income (UMI) group of 0.769 by 2038.

4.1.2 Demographics and the labor force

Registered Syrian refugees in neighboring countries numbered 5,663,675 at the end of 2018 (figure 8.8). World Bank (2019) finds that the key drivers of potential voluntary refugee returns are security and infrastructure services in the home country. On this basis, we link voluntary returns to the reconstruction bill, in that a more optimistic political settlement scenario is associated with greater security and more reconstruction funds being made available. The amount of available funds in turn determines the amount of infrastructure that can be built. Hence, to calculate the baseline and pessimistic scenarios of voluntary mobility (or refugee returns), we use the ratio of reconstruction funds to the optimistic scenario in the first 10 years in each case.

According to the UNHCR (2018) survey, 76% of refugees (4.3 million people) intend to return to Syria one day. This rate of return is also consistent with United Nations population projections. We assume that this is the rate of returnees under the optimistic scenario, with the trajectory based on United Nations data, where the majority of returns occur in the first 10 years. Following this, we assume average population growth of 2.5% over 2019–2038, with the data building in net migration into Syria of 4.21 million over 2020–2035. Of this total, 66% return over 2020–2025 (about 556,000 on average per year), 29% over 2025–2030 (about 240,000 per year), and 5% over 2030–2035 (about 46,000 per year).[17]

Given that in the optimistic scenario reconstruction funds amount to US$125 billion (for the first 10 years) and the return rate stands at 76%—for the moderate scenario of US$70 billion, this would imply a return rate of 43%. Similarly, compared to the optimistic scenario, for a pessimistic scenario of US$30 billion, this would imply a return rate of 18%. Following this, in the moderate and pessimistic scenarios of the voluntary mobility case (43% and 18% return rates, respectively), we calculate average population growth rates of 2.2% and 1.9%, respectively, over 2019–2038. For the forced repatriation case (100% return rate), we obtain an average population growth rate of 2.7% over 2019–2038.

[17] From our calculations using details in the UN population statistics, this is in addition to about 112,000 returnees from mid-2019 to mid-2020, giving a total of 4.3 million returnees, or 76% of registered refugees residing in neighboring countries over 2019–2035.

4.1.3 Human capital

We follow the same approach as in section 3.1.3. Changes in the average years of schooling are estimated based on shifts in the population (including the return of refugees) and improvements in enrollment rates. Where we reduce (voluntary mobility case—moderate and pessimistic scenarios) or increase refugee returns (forced repatriation case) compared to the UN statistics (voluntary mobility case—optimistic scenario), we apportion the adjustment to different age groups based on the UNHCR profile of the age distribution of refugees.

Destroyed/nonfunctioning schools lead to low enrollment rates (World Bank 2019). Further, displaced families will likely be hindered in their attempts to access education services. Since the prospects for reconstruction are relatively weak under the pessimistic scenario, we assume primary and secondary enrollment rates only return to pre-conflict levels (93% and 67%, respectively) by 2038, while the tertiary enrollment rate rises to 50% (from 36%) by that time. This timeline from the given initial levels is roughly in line with the trajectory of estimations/projections of enrollment ratios for developing countries in Barro and Lee (2015) (see their chapter 3, figure 3.5) and is longer than what Syria historically took to reach those rates.[18] We further assume that by 2048 enrollment rates reach 100%, 80%, and 60% respectively at the primary, secondary and tertiary levels. For the optimistic scenario, we assume primary and secondary enrollment rates reach pre-conflict levels in one-half the time, that is, by 2028, and by 2038, 100% and 80%, respectively. For the tertiary enrollment rate, we assume it rises to 50% by 2028 (also in one-half the time compared to the pessimistic scenario) and 60% by 2038. By 2048, we assume enrollment rates reach 90% and 70%, respectively, at the secondary and tertiary levels. With these calculations we obtain years of schooling of 8.449 and 6.991, respectively, by 2038 in the optimistic and pessimistic scenarios of the voluntary mobility case. The projected years of schooling in 2038 under the pessimistic scenario are roughly the same as the pre-conflict value of 7.080. For the moderate scenario, we take an average of years of schooling under the other two scenarios, which gives a value of 7.718 by 2038.

Using the above, average annual growth in human capital is 1.3% under the optimistic scenario and 0.9% in the pessimistic scenario over 2019–2048. The human capital growth under the moderate scenario is a simple average of the growth rates under the other two scenarios. The average years of schooling and human capital growth rates remain similar in the scenarios of the forced repatriation case compared to the voluntary mobility case as there is little change in the population distribution by age groups.

4.1.4 TFP

We assume a gradual rebuilding of the overall TFP determinants index. Under the optimistic scenario, we increase this index from 15.98 in 2018 to 35.42 by 2028 and 75.76 by 2048 based on the trajectory of the Republic of Korea's index over the 30-year period, 1985–2014. Korea is the best performer in the sample of countries used in Kim and Loayza (2019). This gives an average annual TFP growth of 1.4% over 2019–2048 under the optimistic scenario, a rate which implies about 10 years to rebuild TFP to pre-conflict levels. For the pessimistic scenario, we repeat the exercise, but based on the index of the United Arab Emirates (UAE), the best performer among MENA countries. This would imply an increase in Syria's index to only 21.72 by 2028 (still below pre-conflict level) and 32.74 by 2048. The corresponding average annual TFP growth over 2019–2048 for the pessimistic scenario would be 0.3%. For the moderate scenario, we assume TFP

[18] UIS: the net primary enrollment rate rose from 81.9% in 1973 to 94.8% in 1987, while the net secondary enrollment rate increased from 39.3% in 2000 to 66.9% in 2010.

growth rates that are the average of the rates under the optimistic and pessimistic scenarios, which implies an average annual TFP growth of 0.9% over the same time period.

4.2 Simulation of the post-conflict growth outlook

We keep the constant parameters (labor share and depreciation rates) unchanged from the values in the earlier simulations. Default initial conditions as of 2018 (GDP level, GDP per capita level, and K/Y ratios) are drawn from the outcomes of the central projection in section 3. Table 8.6 details the projections of growth drivers post-conflict based on the discussion in section 4.1. Based on the experience of other conflict countries, investment-to-GDP ratios are tied to foreign funding and a gradual recovery in national savings. Other cases of post-conflict recovery also suggest high overall investment rates, for example in the range of 30 to 35% in Lebanon in the 1990s and about 40% in Kuwait following its one-year conflict (Sab 2014).

Under the moderate scenario of the voluntary mobility case, I/Y averages about 43% and 39% over 2019–2028 and 2029–2038; and at 23% and 25%, respectively, under the pessimistic scenario. The pessimistic rate is consistent with the pre-conflict investment rate in Syria. The investment shares are exceptionally high under the optimistic scenario, averaging 63% and 46%, respectively, in the next two decades.

4.2.1 Post-conflict GDP projections across the different scenarios under voluntary mobility

Under the moderate scenario of the voluntary mobility case, average GDP growth is 8.4% over 2019–2038 (figure 8.11a). As can be observed from the top right of figure 8.11b, with the inflow of reconstruction funds, the main growth driver over the 20-year period is capital accumulation. As I/Y reverts to something close to pre-conflict trends especially after the 20-year annual inflow of reconstruction funds, the contribution from human capital growth and TFP are just as relevant as physical capital growth. In this scenario, Syria reaches its pre-conflict GDP level by 2031, and its pre-conflict GDP per capita level by 2033, thus losing about two decades.

In the optimistic scenario, average GDP growth is 10.9% over 2019–2038, with exceptionally high investments, and stronger contributions from other growth drivers relative to the moderate scenario (figure 8.11a and figure 8.11b, bottom left). Even so, it would take Syria 9 years, that is by 2027, to surpass its 2010 GDP level and 11 years to surpass its pre-conflict GDP per capita. In the pessimistic scenario, GDP growth averages 5.1% across the next two decades, only slightly higher than pre-conflict levels, amid limited reconstruction funds from external sources; see figure 8.11b, bottom right, for the difference in growth drivers in relation to the moderate scenario. In this case, it would take Syria at least 22 years to surpass its pre-conflict GDP level and almost 29 years to meet its GDP per capita level. This finding echoes the simulation in World Bank (2017) where under the assumption that the conflict ends in its sixth year (2017), with investment recovering but remaining below its pre-conflict level, Syria's GDP remains below its pre-conflict level even 20 years after the conflict.

4.2.2 Comparing between voluntary mobility and forced repatriation

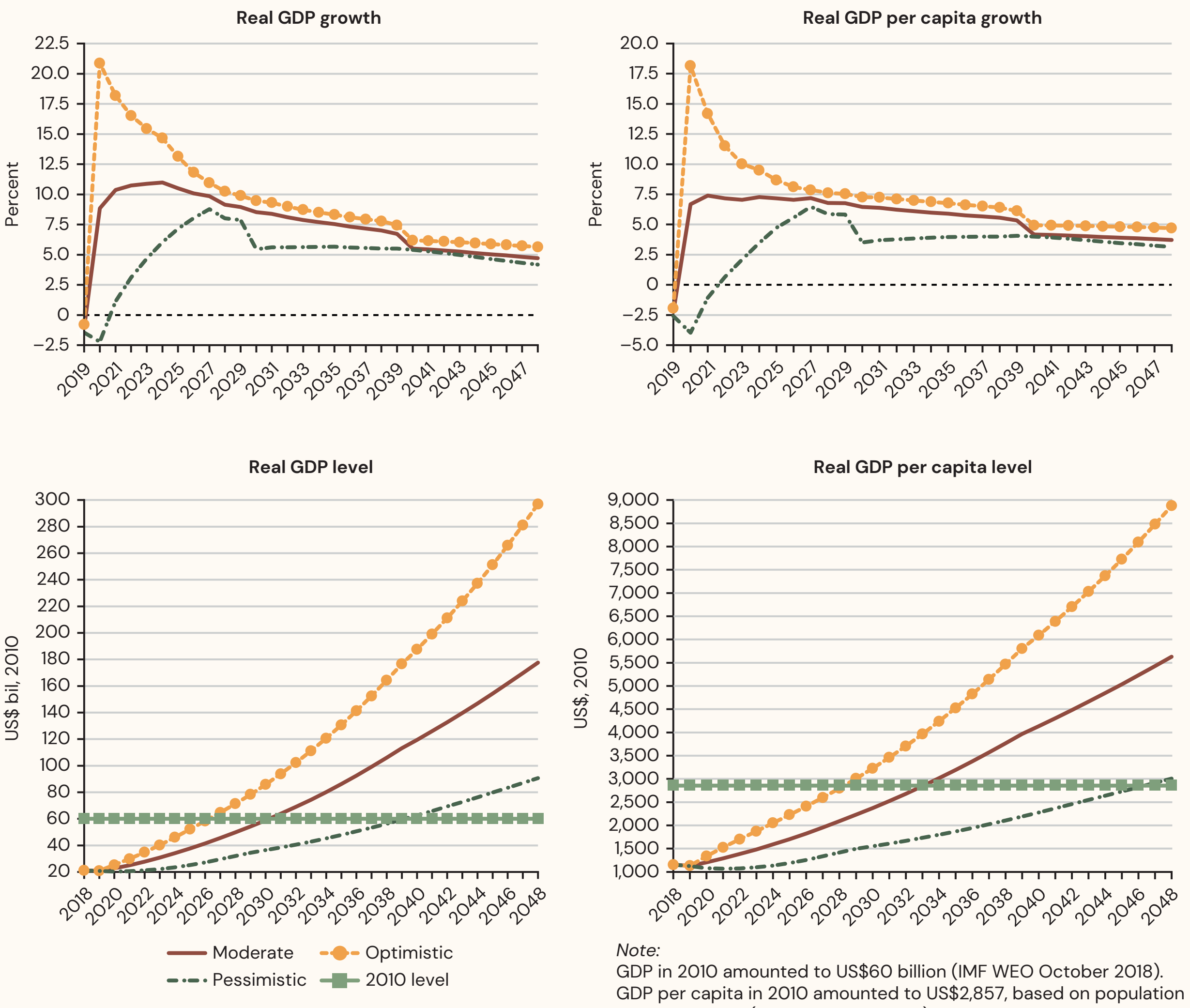
On the one hand, higher population growth from the forced repatriation contributes to higher GDP growth rates, particularly over the time the influx of refugees is expected, and a progressively higher level of GDP given these growth rates (figure 8.12, left). This is a somewhat sanguine perspective, based on the assumption that there are no changes to other factors of production, particularly demographic ratios, labor force participation rates, and human capital characteristics.

Table 8.6: Simulation for Post-Conflict Syria – Projected Variables

Parameter/variable*	Note	2018	Scenario								
			Optimistic			Moderate			Pessimistic		
			Average								
			2019–2028	2029–2038	2039–2048	2019–2028	2029–2038	2039–2048	2019–2028	2029–2038	2039–2048
Public investment-to-output ratio I^G/Y - voluntary mobility case	*(1)*	0.010	0.251	0.185	0.140	0.170	0.157	0.120	0.091	0.100	0.100
- forced repatriation case			0.250	0.183	0.140	0.168	0.155	0.120	0.088	0.100	0.100
Private investment-to-output ratio I^P/Y	*(1)*	0.040	0.376	0.277	0.210	0.255	0.236	0.180	0.136	0.150	0.150
- voluntary mobility case											
- forced repatriation case			0.374	0.275	0.210	0.252	0.232	0.180	0.133	0.150	0.150
Efficiency of new public investment θ^N	*(2)*	0.570	0.625	0.724	0.769	0.615	0.697	0.734	0.570	0.570	0.570
Human capital growth g_h	*(3)*		0.013	0.014	0.011	0.009	0.013	0.011	0.004	0.010	0.012
TFP growth g_A	*(4)*		0.001	0.021	0.020	–0.003	0.015	0.014	–0.009	0.009	0.009
Population growth rate g_N	*(5)*		0.034	0.017	0.011	0.027	0.017	0.011	0.021	0.017	0.012
- voluntary mobility case											
- forced repatriation case			0.039	0.016	0.010	0.039	0.016	0.010	0.039	0.016	0.010
Working-age-to-population share, growth g_ω	*(6)*		0.009	0.002	0.000	0.009	0.002	0.000	0.009	0.002	0.000
Labor force participation rate, growth g_ϱ	*(7)*		–0.001	0.000	0.000	–0.001	0.000	0.000	–0.001	0.000	0.000

Note: *Multiply by 100 to obtain parameter/variable values in percent share or growth terms (%).
(1) The 2018 values are from the central projection under conflict. See section 4.1.1 for details on the scenarios.
(2) The 2018 value is from the central projection under conflict. See section 4.1.1 for details of the scenarios.
(3) See section 4.1.3.
(4) See section 4.1.4.
(5) See section 4.1.2.
(6) United Nations (2017).
(7) May 2018 ILO-modelled estimates up to 2030, held constant thereafter.

Figure 8.11a: Post-Conflict Simulation of GDP in Syria— Scenarios under the Voluntary Mobility Case



Note:
GDP in 2010 amounted to US$60 billion (IMF WEO October 2018).
GDP per capita in 2010 amounted to US$2,857, based on population of 21.018 million (United Nations 2017).

On the other hand (and most importantly), regarding GDP per capita, growth rates under the forced repatriation case are lower over the refugee influx period (figure 8.12, right). For instance, at the height of repatriation in the moderate scenario, GDP per capita growth is lower by 1 percentage point when compared to voluntary mobility. Growth rates recover thereafter. However, GDP per capita levels remain lower in the forced repatriation case than in the voluntary mobility case for the entire period under our review. In the moderate scenario, GDP per capita level is on average lower by US$76 (at 2010 constant prices) over 2019–2048. This is because of lower physical capital in per worker terms, which reduces labor productivity and output per capita relative to the voluntary mobility case. Of all the scenarios, it is the optimistic case where forced repatriation is the least adverse— as refugees already want to return given relatively good conditions for growth.

4.2.3 How long would it take Syria to reach higher income group thresholds?

Prior to the conflict, Syria's gross national income (GNI) per capita based on the World Bank Atlas Methodology (US$1,840 as of 2007) placed it in the LMI category, and at a level that was about one-half the then UMI threshold.

Figure 8.11b: Impact of Different Growth Drivers under the Voluntary Mobility Case

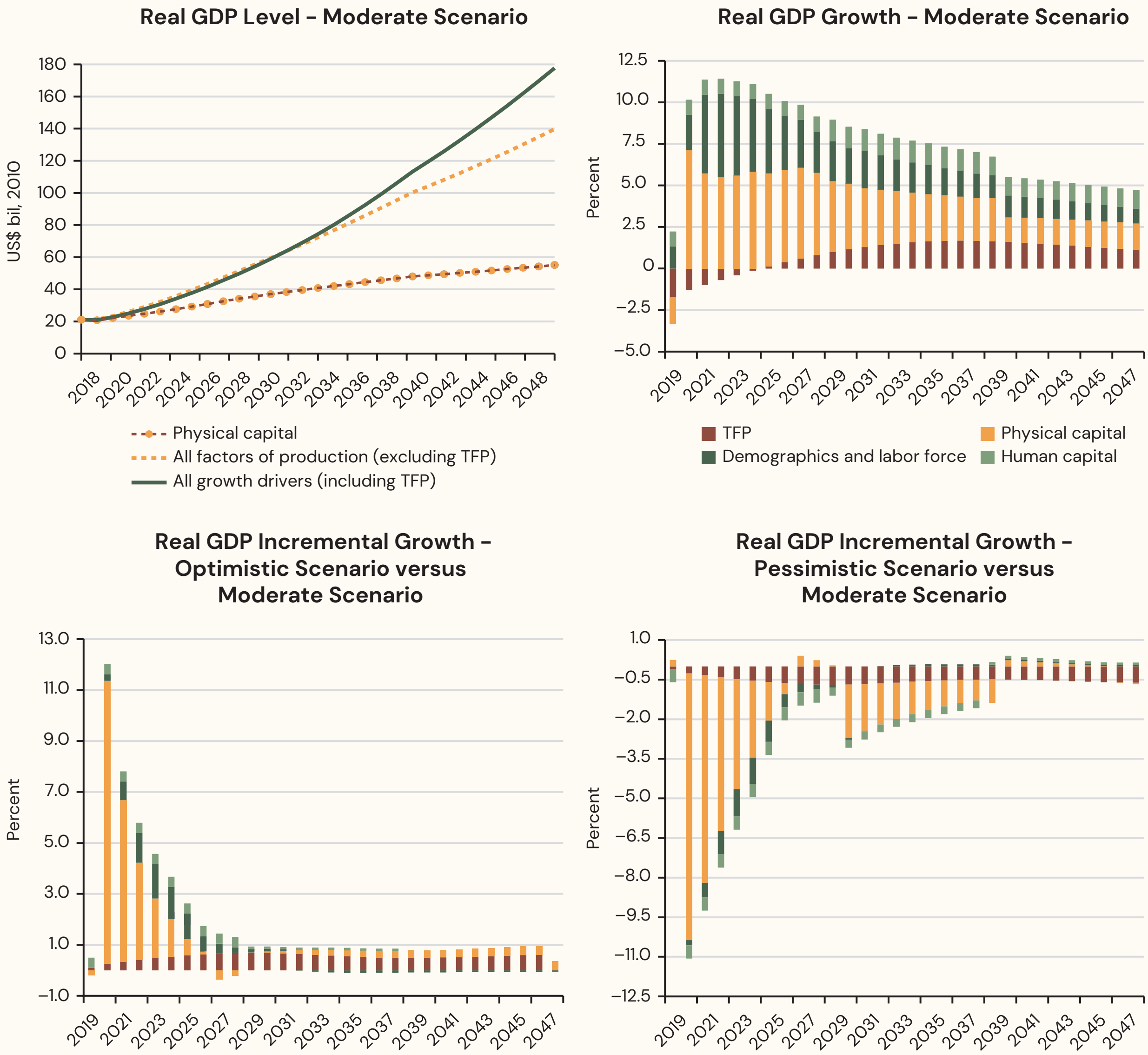
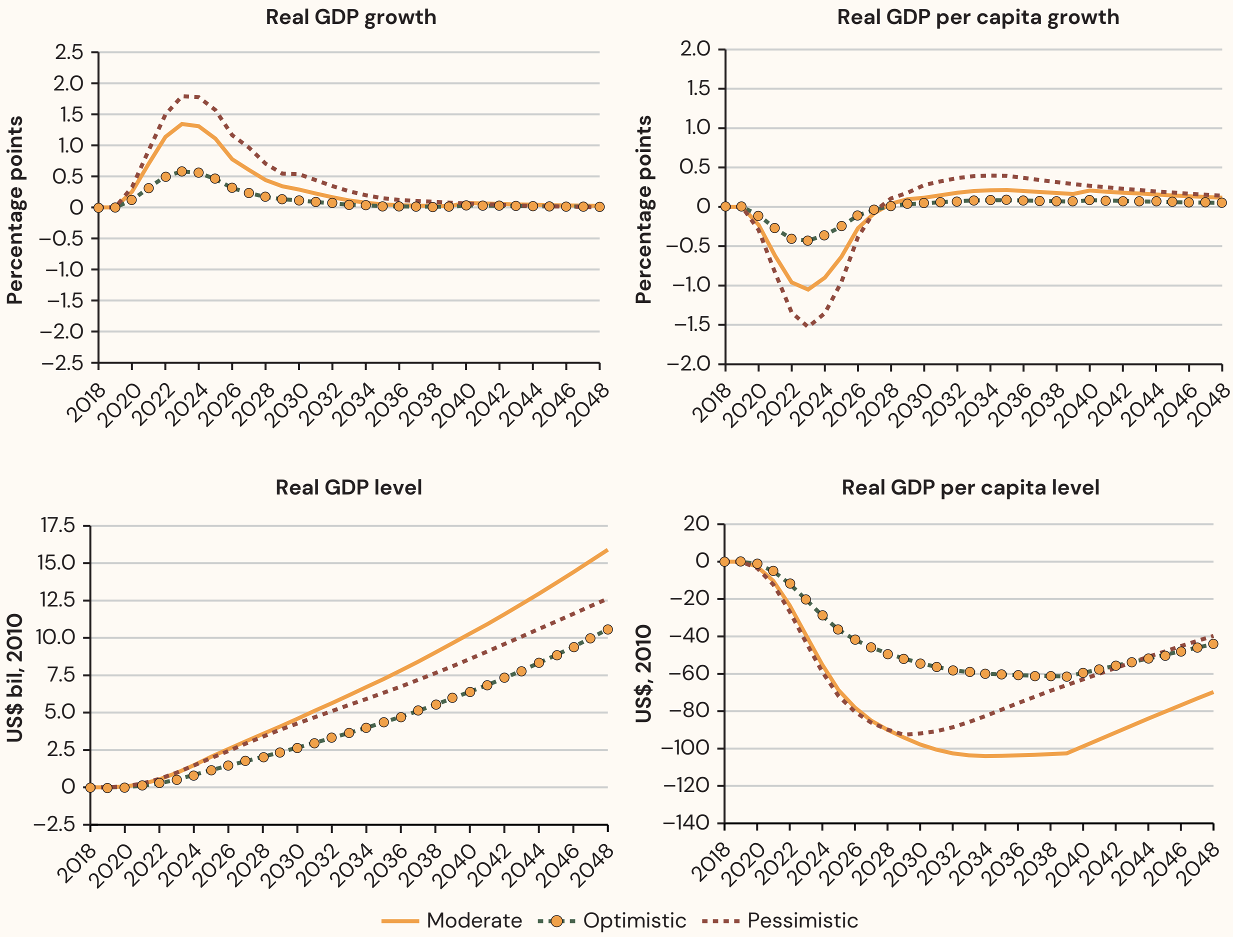
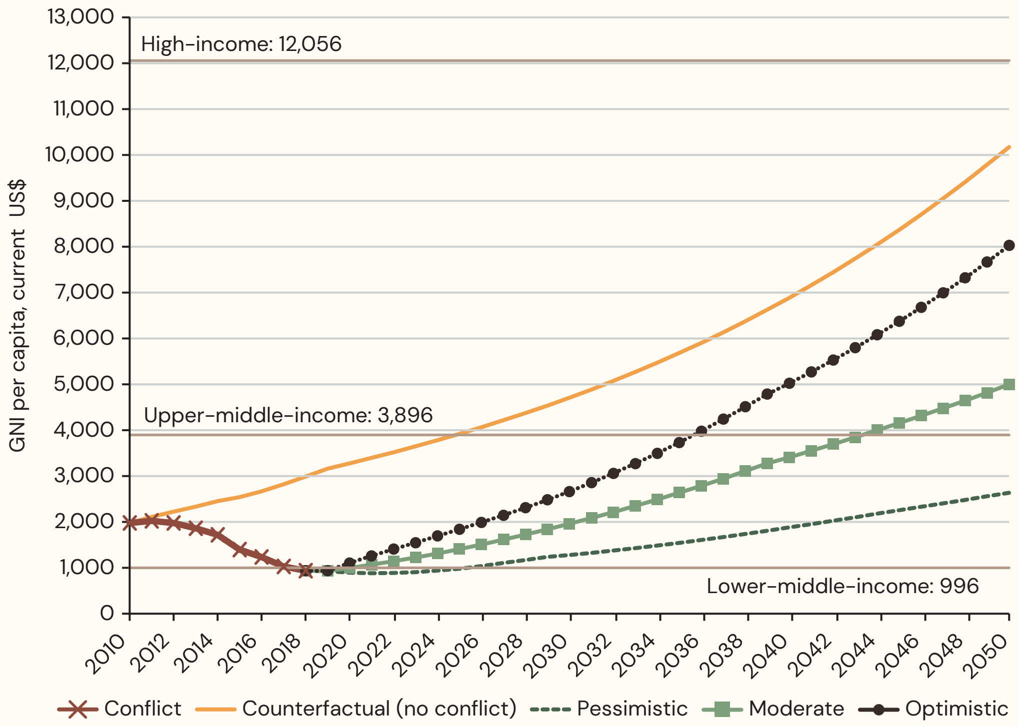


Figure 8.12: Post-Conflict Simulation of GDP in Syria—Incremental/Decremental Effect of Forced Repatriation versus Voluntary Mobility



Note: Each scenario reflects the difference that is calculated as forced repatriation case - voluntary mobility case.

Figure 8.13: **Distance to Higher Income Group Thresholds Based on GNI Per Capita**



Note: GNI per capita based on the World Bank Atlas Methodology for Syria is only available up to 2007. We impute future values based on actual GDP per capita growth up to 2010 (at 2010 prices), our projections for GDP per capita growth over the conflict and post conflict periods (both also at 2010 prices). We account for inflation up to 2019 based on US inflation rates.
On using GDP growth rates to proxy GNI growth rates, our calculations based on pre-conflict data suggest the growth rates of GDP per capita in current US$ and GNI per capita based on the Atlas Methodology on average are quite close (e.g., 1998–2007: 7 percent versus 8 percent; 1993–2007: 5 percent versus 4 percent)
The post-conflict scenarios (pessimistic, moderate and optimistic) reflect the voluntary mobility case.

In figure 8.13, we show that at the tail end of the conflict (using 2018 as a reference point), Syria appears to have fallen just below the LMI threshold. While once again surpassing this threshold is very likely in the next few years, it would possibly take 18 and 26 years under the optimistic and moderate scenarios, respectively, to breach the UMI threshold, and beyond 2050 for the pessimistic scenario. In contrast, in the counterfactual of no conflict, Syria might have passed this level in about six years, that is by 2024. This means that from 2010, while it could have taken Syria 14 years to become an UMI country, it may now take about double, or even triple that time.

5. Conclusion

In this chapter, we use the Long Term Growth Model– Public Capital Extension (LTGM-PC, chapter 2 in this volume) to answer three questions pertaining to Syria's economic growth in the aftermath of its civil conflict: What might have been the counterfactual of no conflict? What was the impact of the conflict? And what are the possible growth paths given different scenarios post-conflict?

Our simulations of the conflict impact suggest an average GDP growth of –12% over 2011–2018, with GDP declining to almost one-third the pre-conflict level. Cumulatively, the loss in GDP amounted to about US$300 billion when compared against the counterfactual. These results are broadly in line with findings in other studies. An added insight is that we identify how the different growth drivers might have contributed to the decline in GDP. Close to 65% of the average negative GDP growth throughout the conflict years is due to physical capital destruction, followed by destruction in labor (15%), TFP (13%), and human capital (7%). This breakdown sets the stage for the analysis of Syria's post-conflict GDP potential, which depends on the projected evolution of these growth drivers.

The post-conflict outlook for the growth drivers depends on the political settlement outcome, which directly affects the availability of reconstruction funds and the voluntary mobility of refugees. Voluntary mobility would not only be preferable on humanitarian grounds but also on economic terms. The political settlement scenario will also affect human capital and productivity growth rates.

In the voluntary mobility case, under our moderate scenario (partial political settlement with strong guarantees for micro-security and property rights), the average GDP per capita growth over 2019–2038 is 6.1%, assuming a final and stable resolution of the conflict. With the inflow of reconstruction funds amounting to US$140 billion spread over 20 years, the main growth driver over the 20-year period is physical capital accumulation amid average investment-to-output of about 41%. As investment-to-output reverts to a lower level, especially after the assumed 20-year annual inflow of reconstruction funds, the contributions from human capital and TFP growth are just as relevant as physical capital growth. Syria reaches its 2010 GDP per capita level by 2033, implying two "lost" decades from conflict.

Under the optimistic scenario (robust political settlement), with exceptionally high investment-to-output of over 60% in the first decade (2019–2029), it would still take Syria about one decade to surpass its 2010 GDP per capita level. Under the pessimistic scenario of limited guarantees for micro-security and property rights, low reconstruction funds of US$30 billion (1.5 times the GDP level in 2018) and investment-to-output close to the pre-conflict average, Syria's GDP per capita reaches its pre-conflict level in about three decades. Respectively for the optimistic and pessimistic scenarios, projected average GDP per capita growth rates over the next two decades (2019–2029 and 2030–2039) are 8.2% and 3.1%, respectively.

While the reconstruction and expansion of physical infrastructure are essential, the importance of strengthening human capital and the factors underlying TFP growth cannot be overstated. We have only accounted for population and enrollment effects on human capital growth. However, the quality of education and health will also likely be impeding factors that would have to be addressed in Syria's quest for growth.

Appendices are available at the journal website: https://doi.org/10.1080/17938120.2021.1930829.

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Chapter 9

Saving and Growth in Egypt[1]

Constantino Hevia and Norman V.Loayza[2]

Abstract

This chapter illustrates the mechanisms linking national saving and economic growth, with the purpose of understanding the possibilities and limits of a saving-based growth agenda in the context of the Egyptian economy. This is done through a simple theoretical model, calibrated to fit the Egyptian economy, and simulated to explore different potential scenarios. The main conclusion is that if the Egyptian economy does not experience progress in productivity—stemming from technological innovation, improved public management, and private-sector reforms—, then a high rate of economic growth is not feasible at current rates of national saving and would require a saving effort that is highly unrealistic. For instance, financing a constant 4% growth rate of gross domestic product (GDP) per capita with no TFP improvement would require a national saving rate of around 50% in the first decade and 80% in 25 years! However, if productivity rises, sustaining and improving high rates of economic growth becomes viable. Following the previous example, a 2% growth rate of TFP would allow a 4% growth rate of GDP per capita, with a national saving rate in the realistic range of 20-25% of GDP.

JEL: O40, O47, E21.
Keywords: Savings; economic growth; Total Factor productivity; Egypt.

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[1] **Editors' note:** This chapter is a reprint of Hevia, C., and N. Loayza. 2012. "Saving and Growth in Egypt." *Middle East Development Journal*, Vol. 4, No. 1, and an earlier version as World Bank Policy Research Working Paper WPS 5529. This chapter represents the first version of the model that would go on to evolve into the standard LTGM (chapter 1) several years later. As such, the model presented in the chapter differs in notation and substance from the main LTGM of chapter 1. Appendices are available at the journal website: https://doi.org/10.1142/S1793812012500022. Affiliations are based on when the paper was written, not necessarily current affiliations.

[2] Constantino Hevia and Norman V.Loayza, World Bank. Corresponding author email: nloayza@worldbank.org. The views expressed in this paper are those of the authors, and do not necessarily reflect those of the World Bank, their Boards of Directors, or the countries they represent.We are grateful to Minister Mahmoud Mohieldin, Farrukh Iqbal, Santiago Herrera, Inessa Love, Alan MacArthur, Tarek Moursi, Brian Pinto, Ritva Reinikka, Luis Servén, Lyn Squire, and two anonymous referees for useful insights and comments. We are indebted to Hoda Youssef and Yuki Ikeda for data collection and to Tomoko Wada for editorial assistance.

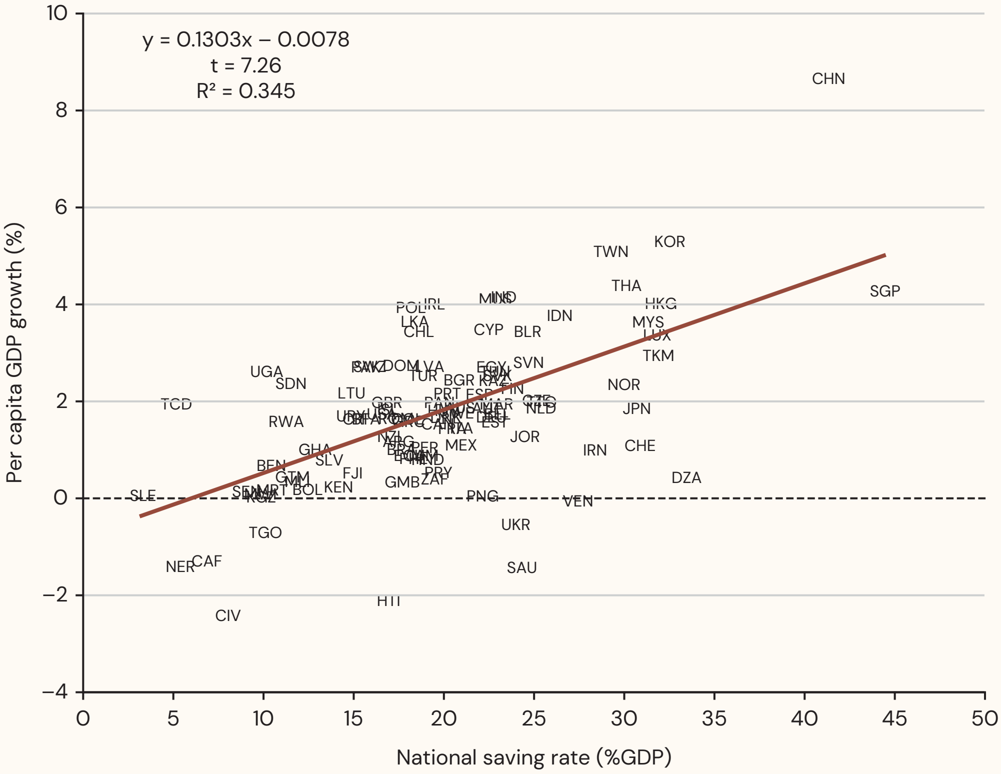
Introduction

The relationship between national saving and economic growth is quantitatively strong and robust to different types of data and methodologies (Mankiw et al. 1992; Attanasio et al. 2000; Banerjee and Duflo 2005; among many others). Countries that have high saving rates for long periods of time tend to experience large and sustained economic growth. A prime example is the experience of the developing countries in East Asia, such as China, Singapore, the Republic of Korea, Malaysia, Thailand, and Taiwan (Young 1995; figure 9.1).

It is only understandable, therefore, that goals to increase economic growth usually refer back to concerns for raising national saving. In the last decades Egypt has been above the typical (or median) country in the world regarding both growth and saving. Its development aspirations, however, require a stronger performance on both accounts.

To be sure, some of the relationship between growth and saving reflects the positive impact that higher income has on improved saving (Loayza, Schmidt-Hebbel, and Serven 2000). However, no less important is the causality that runs from higher saving to larger growth, where the mechanism resides on the well-known process of capital accumulation. Improved national saving provides the funds to take advantage of more and larger investment opportunities. This, in turn, increases the capital stock which, when effectively used for economic production contributes to higher output growth. Although in theory domestic investment does not have to be supported by national saving, in practice the connection between the two is quite close. This is especially true in the long run, when external sources of funds can be tapped only in a restricted manner: large current account deficits cannot be sustained indefinitely. This is exemplified by the strong

Figure 9.1: Saving and Growth: Average, 1980–2008

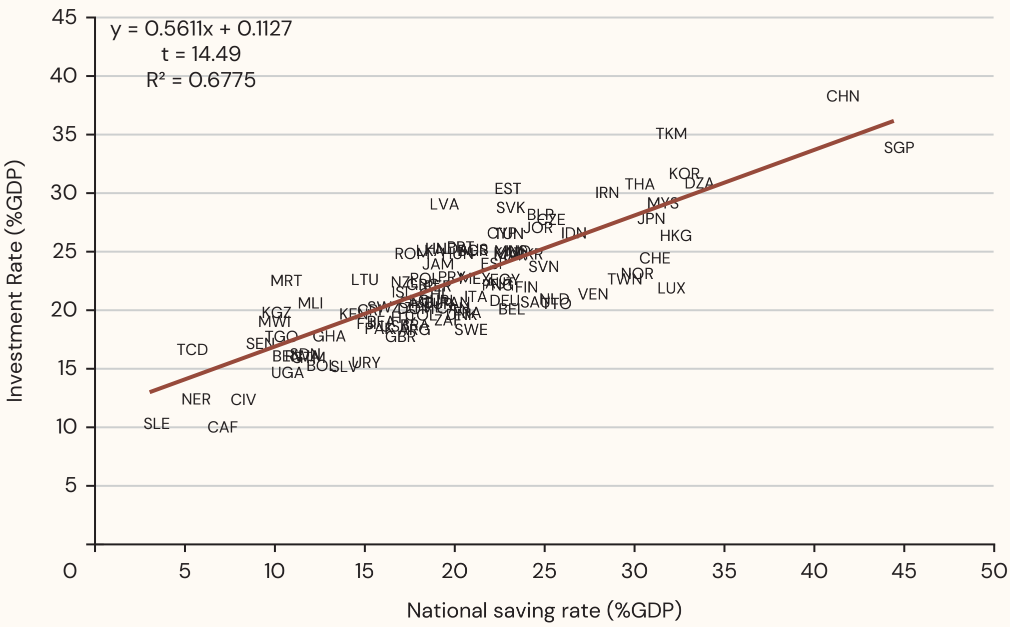


relationship between the average saving and investment rates across countries in the last three decades, as depicted in figure 9.2. Mirroring its saving-growth situation, Egypt conforms to the cross-country pattern regarding the relationship between saving and investment. The links in the relationship between saving and growth are not, however, mechanical but depend on the quality of the financial system and public institutions in general. Without an efficient financial system, the best investment opportunities will not be matched with the available saving (Levine 2005). Likewise, without proper public institutions (that guarantee macroeconomic stability and contract enforcement, for instance), accumulated capital may remain idle or ineffectively used (Hall and Jones 1999; Easterly and Levine 2001). This points to the crucial importance of the efficiency or productivity with which physical capital, human capital, and labor are used in the production process. The growth of factor productivity is what in the end determines whether a saving and investment effort will result (or not) in improved economic growth.

The objective of this study is to illustrate the mechanisms linking national saving and economic growth in Egypt. We will do this through a simple theoretical model, calibrated to fit the Egyptian economy, and simulated to explore different potential scenarios. Our goal is to understand the two-way connection between saving and growth and the possibilities and limits of a saving-based growth agenda, in the context of the Egyptian economy.

The optimality of saving behavior can be addressed from different angles. The most common in the academic literature is the perspective of optimal saving as the behavior that maximizes a consumer welfare function. This, however, may be too abstract for the needs and objectives of policy practitioners. For this reason, we pose the problem of optimal saving from the perspective of financing a given rate of economic growth while simultaneously achieving external sustainability. First, we present the basic elements of a simple model, constructed with the purpose of understanding optimal saving from this perspective. Next, we calibrate the model to the Egyptian economy, using parameters and relationships obtained in the received literature for the country. Using the calibrated model, we perform some simulations that clarify the relationships between saving, productivity, and growth, allowing us to discuss policy options for improving economic growth in Egypt.

Figure 9.2: Saving and Investment: Average, 1980–2008



1. A Simple Model

We consider a model of an open economy with a single sector that produces a unique final good, which we call "gross domestic product" or, simply, output. (In the appendix we examine an extension of the model to allow for multiple production sectors.) The economy evolves in discrete time, and each time period, denoted by an index *t*, represents one year.

We assume that the economy has access to a technology to produce output by combining capital and labor inputs according to the production function

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{1}$$

where Y_t denotes output, K_t is the stock of physical capital, L_t denotes the amount of effective labor input, A_t is a measure of the level productivity of capital and labor, and the technology parameter $\alpha \in \hat{I}\ (0,1)$ measures the relative contribution of capital to the production of output—in a competitive economy, the parameter α coincides with the share of output distributed as payments to capital. As mentioned above, in the appendix we consider a multi-sector version of the model, where each sector has its own productivity parameter and factor shares. There, we examine the possibility that each sector faces specific distortions to output and capital/labor allocations. The multi-sector version of the model allows us to interpret changes in aggregate productivity as reflecting changes in both sectoral productivities and sectoral allocation distortions.

We abstract from distributional issues and assume that labor is homogeneous across the population. Following Bils and Klenow (2000) and Hall and Jones (1999) we assume that every worker has been trained with E_t years of schooling with ϕ rate of return per year of education, delivering productivity $e^{\phi E_t}$ per worker. Thus, effective labor is given by

$$L_t = e^{\phi E_t} N_t, \tag{2}$$

where N_t denotes the total number of workers. In this specification, ϕE_t measures the relative efficiency of a worker with E_t years of schooling relative to one with no schooling. Note that in this formulation, a worker's efficiency depends not only on the years of schooling but also on the quality and relevance of education for production purposes.

Capital depreciates at a constant rate δ between time periods, but can be augmented through investment. Namely, the stock of capital evolves according to

$$K_{t+1} = (1 - \delta) + I_t \tag{3}$$

where I_t denotes aggregate investment.

Abstracting from valuation changes, the current account deficit at period *t*, CAD_t, is defined as the change in net foreign liabilities of the whole economy; that is,

$$CAD_t \equiv B_{t+1} - B_t = rB_t + C_t + G_t + I_t - Y_t - TR_t, \tag{4}$$

where B_t is the stock of net foreign liabilities due at period *t*; *r* is the world interest rate, assumed constant for simplicity; C_t denotes private consumption; G_t denotes government expenditures; and TR_t denotes the flow of net external current transfers (worker remittances plus official grants) that are not reflected as changes in the country's net foreign liabilities.[3]

[3] Historically, workers' remittances and official grants to Egypt have been an important fraction of GDP, averaging about 5% in the present decade.

If we let $S_t^N = Y_t + TR_t - rB_t - C_t - G_t$ denote aggregate national saving, the previous equation can be rearranged into the familiar investment-saving gap identity of an open economy,

$$I_t = S_t^N + CAD_t. \tag{5}$$

That is, domestic investment I_t can be financed through national saving or through external borrowing (i.e., foreign saving).

External solvency requires that the current value of foreign liabilities be no larger than the present value of net exports, and can be obtained by iterating forward on the current account identity, equation (4), namely,

$$\sum_{j=0}^{\infty} \frac{1}{(1+r)^j}\left[Y_{t+j} + TR_{t+j} - I_{t+j} - C_{t+j} - G_{t+j}\right] = (1+r)B_t.$$

This solvency condition imposes certain assumptions about the functioning of international capital markets that are difficult to reconcile with the experience of emerging market economies. In particular, it fails to capture the financial frictions that are pervasive in developing countries. For this reason, we follow Milesi-Ferretti and Razin (1996) and impose a sufficient condition for current account sustainability that is also appealing in terms of its realism.

We assume that the economy is required to maintain the ratio of foreign debt to gross domestic product constant, namely, that

$$\frac{B_t}{Y_t} = \beta \text{ for all } t. \tag{6}$$

This constraint can be due to the reluctance of foreigners to lend money when the level of debt is sufficiently high, or because the government wants to maintain a safe level of foreign borrowing relative to output.[4]

Using the definition of the current account, the last constraint imposes the following restriction on the current account deficit as a fraction of gross domestic output,

$$\frac{CAD_t}{Y_t} = \frac{B_{t+1}}{Y_{t+1}}\frac{Y_{t+1}}{Y_t} - \frac{B_t}{Y_t} = \beta\left(\frac{Y_{t+1}}{Y_t} - 1\right). \tag{7}$$

That is, the ratio of the current account deficit to the value of output depends upon the net foreign liabilities as a fraction of GDP, β, and on the growth rate of output, Y_{t+1}/Y_t. For example, if the economy is a net borrower ($\beta > 0$) and contemplates growing ($Y_{t+1} > Y_t$), then it must necessarily run a current account deficit.

We find it convenient to rewrite all previous equations in per-worker terms. Introducing the definition of effective labor equation (2) into the production function equation (1) and dividing the resulting expression by N_t gives

$$y_t = A_t k_t^{\alpha}\left(e^{\phi E_t}\right)^{1-\alpha} \tag{8}$$

where $y_t = Y_t/N_t$ denotes output per worker and $k_t = K_t/N_t$ is capital per worker. More generally, throughout the chapter lowercase letters are used to denote variables in per-worker terms.

[4] Alternatively, we could assume that the interest rate that the country pays on its foreign debt, r, depends on the difference between the actual and some target level of the debt-to-GDP ratio. With this modification, there is an endogenous risk premium that induces the debt-to-GDP ratio to converge to the target value in the long run (Schmitt-Grohé and Uribe 2003). Because of this fact, we conjecture that the main message of the paper is the same in the alternative model.

Following the same approach, we write the equilibrium equations (3), (5), and (7) in per-worker terms,

$$k_{t+1}(1+\gamma_{Nt}) = (1-\delta)k_t + i_t, \tag{9}$$

$$i_t = s_t^N + cad_t, \tag{10}$$

and

$$\frac{cad_t}{y_t} = \beta\left[(1+\gamma_{yt})(1+\gamma_{Nt})-1\right]. \tag{11}$$

where $\gamma_{Nt} = N_{t+1}/N_t - 1$ denotes the growth rate of the workforce between periods t and $t+1$. More generally, we denote by γ_{xt} the (net) growth rate between periods t and $t+1$ of any variable x_t.

We now use the previous equations to write a condition that relates saving and growth. First, we use the production function, equation (8) at periods t and $t+1$ to write the growth rate in output per worker as

$$(1+\gamma_{yt}) = (1+\gamma_{At})(1+\gamma_{kt})^{\alpha}\left[e^{\phi(E_{t+1}-E_t)}\right]^{1-\alpha} \tag{12}$$

That is, the (gross) growth rate of output $(1+\gamma_{yt})$ depends upon the growth rate of productivity $(1+\gamma_{At})$, the growth rate of the stock of capital $(1+\gamma_{kt})$, and the growth rate of human capital $e^{\phi(E_{t+1}-E_t)}$.

Second, introducing the investment-saving equation (10) into the capital accumulation equation (9) and rearranging gives

$$(1+\gamma_{kt})(1+\gamma_{Nt}) = 1-\delta+\frac{i_t}{y_t}\frac{y_t}{k_t} = 1-\delta+\left(\frac{s_t^N + cad_t}{y_t}\right)\frac{y_t}{k_t}.$$

This equation describes the growth rate of the stock of capital per worker as a function of the growth rate of the workforce γ_{Nt}, the depreciation rate δ, the national saving ratio with respect to output S_t^N/y_t, the current account deficit as a fraction of GDP cad_t/y_t, and the degree of capital deepening in the economy k_t/y_t.

Imposing the sustainability condition, equation (11) into the last equation, the evolution of the capital stock becomes

$$(1+\gamma_{kt})(1+\gamma_{Nt}) = 1-\delta+\left\{\sigma_t + \beta[(1+\gamma_{yt})(1+\gamma_{Nt})-1]\right\}\frac{y_t}{k_t}, \tag{13}$$

where $\sigma_t = s_t^N/y_t$ denotes the national saving ratio with respect to GDP.[5]

Finally, introducing equation (13) into the output growth equation (12) gives an expression that links the growth rate of output per worker to the national saving ratio σ_t, the growth rate of productivity γ_{AT}, the growth rate of the workforce γ_{NT}, the increase in human capital $\phi(E_{t+1}-E_t)$, and the level of capital deepening k_t/y_t,

$$(1+\gamma_{yt}) = (1+\gamma_{At})\left[\frac{1-\delta+\left\{\sigma_t+\beta[(1+\gamma_{yt})(1+\gamma_{Nt})-1]\right\}\frac{y_t}{k_t}}{1+\gamma_{Nt}}\right]^{\alpha} e^{(1-\alpha)\phi(E_{t+1}-E_t)}. \tag{14}$$

[5] Note that s_t^N/y_t is neither the national saving rate nor the domestic saving rate as defined in the national accounts statistics. The national saving rate is defined as s_t^N/y_t^N where $y_t^N = y_t - rb_t + TR_t$ is national disposable income, whereas the domestic saving rate is defined as s_t^D/y_t, where $s_t^D = y_t - c_t - g_t$ is domestic saving.

We use equation (14) in our numerical experiments.

To understand the implications of the previous equation, we take logarithms and use the approximations $\log(1 + x) \approx x$ for small x and $xy \approx 0$ for small x and y to write equation (14) as,[6]

$$\gamma_{yt} = \gamma_{At} + \alpha\left[\left(\sigma_t + \beta\left[\gamma_{yt} + \gamma_{Nt}\right]\right)\frac{y_t}{k_t} - \delta - \gamma_{Nt}\right] + (1-\alpha)\phi(E_{t+1} - E_t).$$

Solving for the growth rate of output gives

$$\gamma_{y,t} = \frac{\gamma_{At} + \alpha\left[(\sigma_t + \beta\gamma_{Nt})\frac{y_t}{k_t} - \delta - \gamma_{Nt}\right] + (1-\alpha)\phi(E_{t+1} - E_t)}{1 - \alpha\beta y_t / k_t}$$

This equation shows that output growth is positively associated with the national saving ratio and with the growth rate in productivity, the workforce, and human capital. As the economy grows, however, the capital-GDP ratio k_t/y_t changes as well. Therefore, the level of saving required to finance a given growth rate in output per worker varies through time.

Productivity growth is determined exogenously and directly in this version of the model. In the multi-sector extension examined in the appendix, aggregate productivity growth depends on both sectoral productivity improvements (proportional to the importance of the sector in final output) and the (sudden or gradual) elimination of any sector-specific distortion. While the former can be a continuous and permanent process, the latter can only have a temporary impact (until the reallocation of resources across sectors is completed).

Throughout the chapter, we have assumed that investment is fully transformed into capital (see equation (3). However, the efficiency of investment to generate productive capital may be diminished in contexts of institutional or regulatory weaknesses (Rodrik and Subramanian 2009). To the extent that these weaknesses may also have a negative impact on TFP improvements, they would reinforce the need for higher savings to achieve a given rate of economic growth. This effect would be moderated, nonetheless, if higher saving rates in turn have a positive impact on the efficiency of investment. This may occur through a variety of channels, for example, the beneficial effect of higher savings on the quality of financial intermediation (Allen and Gale 2000) and the competitiveness of the exchange rate (Rodrik 2008).[7]

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[6] This approximation is only for illustration purposes. We always use equation (14) to compute the experiments.

[7] Consider the standard model as described in the text, but assume that the capital accumulation equation is given by $K_t = (1 - \delta)K_t + \lambda I_t$ so that λ represents the efficiency of each unit of investment. The baseline model assumes $\lambda = 1$; however, in a context of, for instance, institutional weakness where investment *expenditures* do not fully lead to productive capital, λ may be lower than 1. Considering this possibility, the only thing that changes in equation (14) is that the term y_t/k_t now appears multiplied by the parameter λ. Therefore, solving for the saving ratio, σ_t, given a target growth rate, γ_{yt}, leads to

$$\sigma_t = \frac{1}{\lambda}\frac{k_t}{y_t}\left[(1+\gamma_{Nt})\left(\frac{1+\gamma_{yt}}{(1+\gamma_{At})e^{(1-\alpha)\phi(E_{t+1}-E_t)}}\right)^{1/\alpha} - 1 + \delta\right] - \beta\left[(1+\gamma_{y\,t})(1+\gamma_{Nt}) - 1\right]$$

Everything else constant, the lower the efficiency of investment (smaller λ), the higher the saving rate would have to be in order to achieve the same growth rate. On the other hand, if the efficiency of investment depended positively on the saving rate (through the mechanisms mentioned in the text), the need for higher saving rates would be correspondingly moderated.

2. Model calibration

We use the relationship imbedded in equation (14) to illustrate the mechanisms linking saving and growth applied to the Egyptian economy. The first step is to use information specifically related to Egypt to calibrate the model. The main pieces of information are the following:

- The current capital-output ratio: k_t/y_t= 2.6. This is the ratio estimated for the year 2008, using the methodology and basic information from Loayza and Honorati (2007). This chapter applies the perpetual inventory method to accumulate investment in order to produce a measure of the capital stock. For this purpose, it uses a depreciation rate of 0.04, consistent with that used in this study (see below).
- The capital share in output: $\alpha = 0.5$. This is an average of the most sensible estimates available. Using time-series analysis, Loayza and Honorati (2007) estimate the capital share in Egypt, to be 0.35. This is also the average across countries that Bernanke and Gürkaynak (2002) obtain using factor payment data from national accounts. Herrera (2009) uses a combination of national accounts information and labor survey data for Egypt to arrive at a larger estimate of the capital share in Egypt, 0.6.
- The annual capital depreciation rate: $\delta = 0.04$. This is the depreciation rate used in the estimation of the capital stock and follows the seminal work of Nehru and Dhareshwar (1993).
- The annual growth rate of the labor force: $\gamma_{Nt} = 0.025$. This is the average growth rate of the number of workers for the period 2001–2008, as estimated from Egypt's national employment statistics. This represents an update of the estimate presented in Loayza and Honorati (2007).
- The annual average increase in education: $(E_{t+1} - E_t) = 0.12$. Education is proxied by the average number of schooling years in the adult population, as reported in Said (2008) for Egypt for the period 1980–2000. This estimate for the average increase in schooling is similar to that obtained using the Barro and Lee (2001) database for the same period.
- The average annual rate of return to education: $\phi = 0.05$. This is proxied by the average rate of return for each year of schooling, as reported in Herrera (2009) for Egypt for the period 1988–2006.
- The current (or targeted) level of net foreign liabilities as a ratio to GDP: $\beta = 0.2$. This corresponds to the official "international investment position" on average for the period 2001–2007, as reported by the International Monetary Fund's (IMF's) Balance of Payments Statistics.
- Net income plus transfers from abroad, as a ratio to GDP: $\left(-r\beta + \frac{tr_t}{y_t}\right) = 0.052$. The numerator of this ratio is equal to the difference between Gross National Disposable Income (GNDI) and gross domestic product (GDP), and the ratio corresponds to the average for the period 2001–2007. It is obtained from statistics reported by the World Bank and the IMF.

Productivity scenarios. A key parameter in the simulations presented below is the rate of growth of total factor productivity, γ_{AT}. The available estimated rates of TFP growth in Egypt vary according to the period under consideration and the method of estimation (Herrera 2009; Loayza and Honorati 2007). They range from approximately –1.5% to 2.5%, with the extreme rates lasting for short periods of time. Our goal here is to establish what a reasonable range is for TFP growth for long periods of time (say 25 years, the simulation horizon). On the one hand, it is difficult to understand how TFP growth rates can be negative for a sustained period of time, unless there is prolonged macroeconomic disarray (e.g., hyper-inflation, civil conflict, or systemic financial crisis). In times of socioeconomic stability, a reasonable lower bound for a TFP growth rate is 0, representing lack of progress. On the other hand, it is also difficult to accept long-run TFP growth rates that exceed those that the highest growing countries have been able to achieve for a sustained period of time. According to the TFP growth estimates presented in Bernanke and Gürkaynak (2002), only the top 5 percent of countries in the world have been able to achieve an average growth rate of TFP around 2% during the period 1965–1995. This, then, seems to be a reasonable upper bound for TFP growth for a sustained period of time in Egypt. In the simulations that follow, we will consider three scenarios: pessimistic, moderate, and optimistic, depending on whether the TFP growth rate is 0%, 1%, or 2%, respectively.

3. Simulations of the Model

Using the model developed above and the calibration parameters, we can perform different numerical exercises to give answers and insights regarding the links between saving, investment, and growth. We perform two basic, complementary simulations. The first one is designed to measure the saving rates that are required to finance a given rate of economic growth. This rate is set to 4% of GDP growth per worker. Although ambitious from historical and cross-country perspectives, this rate corresponds to the average that Egypt has been able to obtain in the last three years and approaches the rate that policy makers set as the target for the country. The second simulation changes perspectives and asks what economic growth rates can be financed if the saving rate is fixed at a given level. This is set to 20% of national saving with respect to GDP. It is a realistic rate, corresponding to the average Egypt has been able to achieve in the last few years.

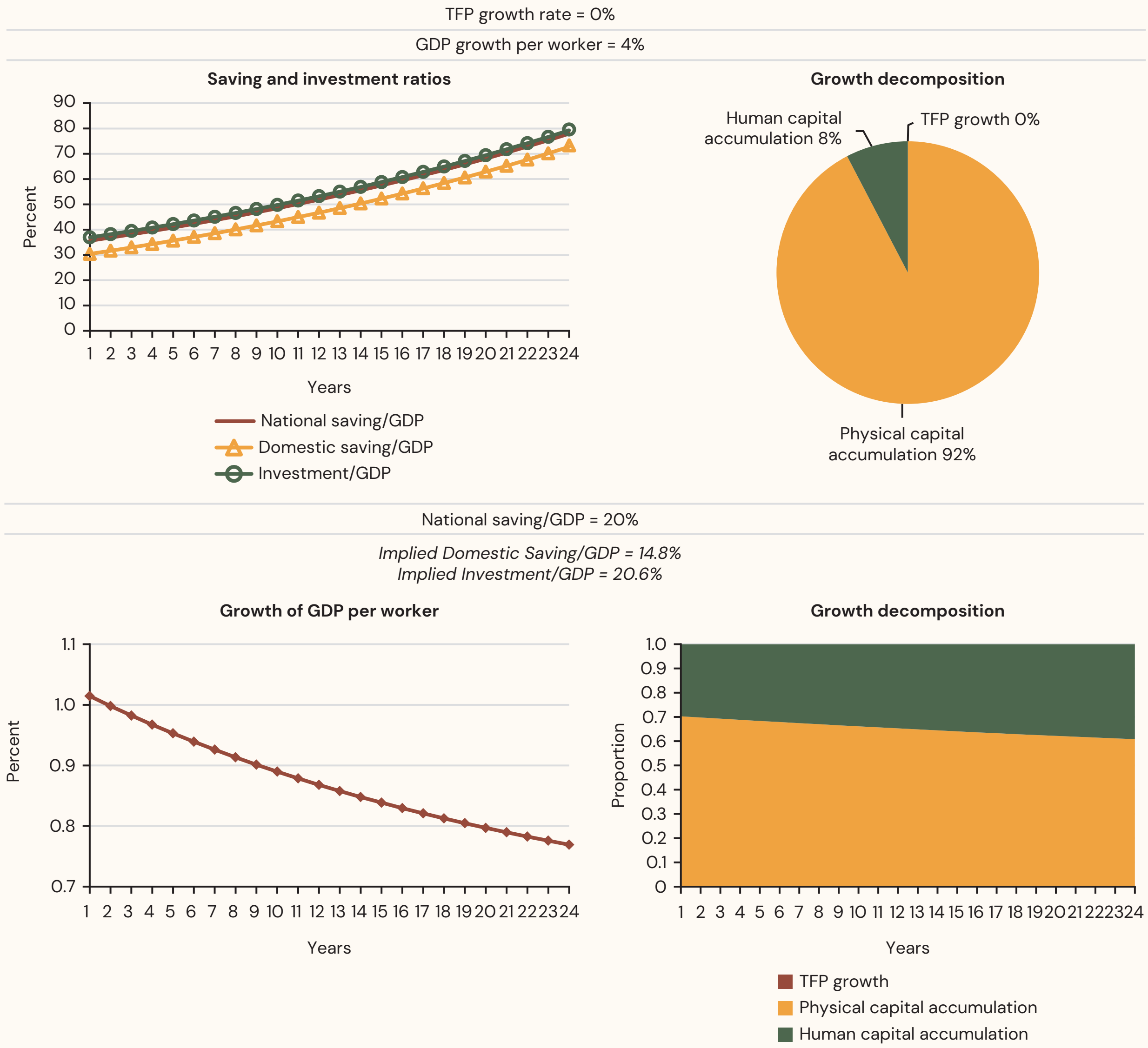
Both simulations are dynamic in the sense that they follow the evolution of the economy for an extended period of time, chosen to be 25 years in our case. Also in both cases, we compute the corresponding Solow growth decomposition in order to understand the role played by factor accumulation and productivity advances in the process of economic growth.

As mentioned in the previous section, the simulations are performed under three scenarios regarding the behavior of total factor productivity. Respectively, TFP growth is assumed to be 0%, 1%, 2%, and the corresponding scenarios are labeled pessimistic, moderate, and optimistic, respectively. The simulation results are presented in figures 9.3, 9.4, and 9.5. In each of them, the upper panels correspond to the simulation where the growth rate of GDP per worker is fixed and the saving rate changes to obtain such growth; and, conversely, the lower panels show the simulation where the saving rate is fixed and economic growth changes in reaction to it.

Let us start with the pessimistic scenario of lack of progress in total factor productivity (figure 9.3). The first simulation (upper panel) shows that, in the absence of TFP growth, the demands on capital accumulation to attain the goal of 4% growth are excessively large. In fact, as the growth decomposition indicates, more than 90% of GDP per-worker growth would have to be supported by physical capital accumulation. (Following its historical trend, human capital would contribute only 0.3 percentage points of GDP growth per worker). The investment rate would need to jump to around 37% of GDP and then increase even further over time as the marginal returns to capital decrease. The limits to external financing imposed by current account sustainability imply that foreigners may supply only a small fraction of capital investment. Thus, national saving would have to almost fully match investment, increasing enormously, first to about 35% of GDP, then to 50% in 10 years, and to almost 80% by the end of the 25-year period. Domestic saving would need to increase by a smaller amount given the substantial remittances and official grants that Egypt receives (of the order of 5% of GDP). Even so, domestic saving would need to jump to twice its recent average and increase from there. Clearly, growing at 4% of GDP per worker cannot be sustained by capital accumulation in a context of nil TFP growth and a small contribution from human capital.

The second simulation (figure 3.9, lower panel) provides rather realistic results when TFP growth is absent. It shows that with a national saving ratio of 20% of GDP, the growth rate of GDP per worker will start at 1.00% and then decrease gradually to 0.75% in 25 years. The decrease in growth is explained by diminishing returns to capital, which in this simulation is accumulated at a constant rate (dictated, naturally, by the

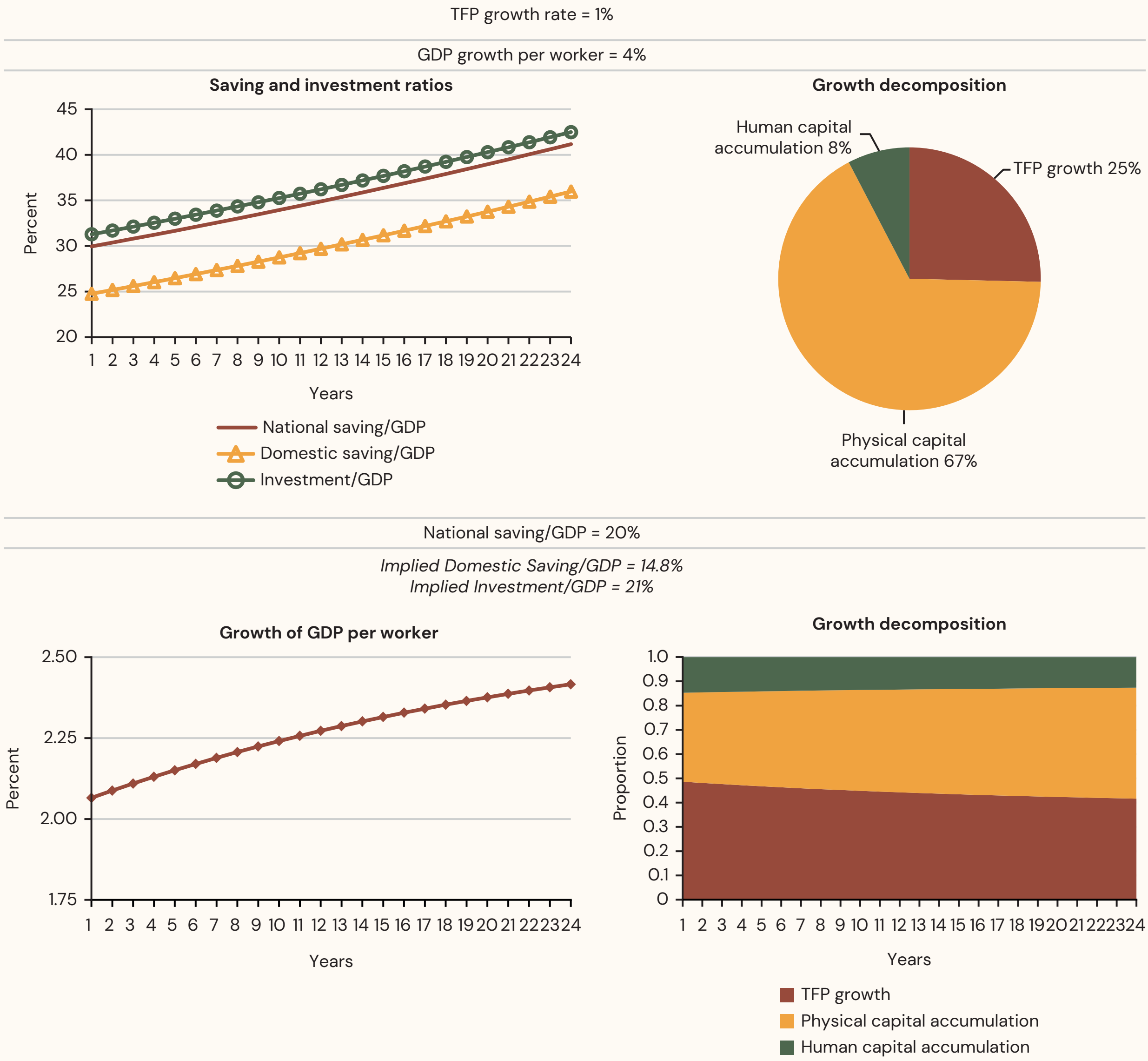
Figure 9.3: Pessimistic Scenario



fixed saving ratio). The contribution of physical capital to economic growth declines over time (implying a declining share with respect to that of human capital in the Solow growth decomposition, shown on the right side of the lower panel).

Let us now turn to the moderate scenario, where TFP grows at a constant rate of 1% (figure 9.4). The first simulation indicates that achieving a target of GDP per worker growth rate of 4% is still a difficult goal. It would require a jump in national saving/GDP from the current 20% to about 30% and then a further increase over time to around 40% in 25 years. (As explained above, investment would be larger than national saving given the participation of foreign investors, and domestic saving lower than national saving because of net transfers from abroad in the form of official grants and workers' remittances.) The lion's share of the contribution to growth would still need to come from capital accumulation, with one-fourth coming from TFP growth (see Solow growth decomposition on the right side of the upper panel). However, although the required increase in national saving is substantial, it is no longer infeasible (as was the case

Figure 9.4: Moderate Scenario



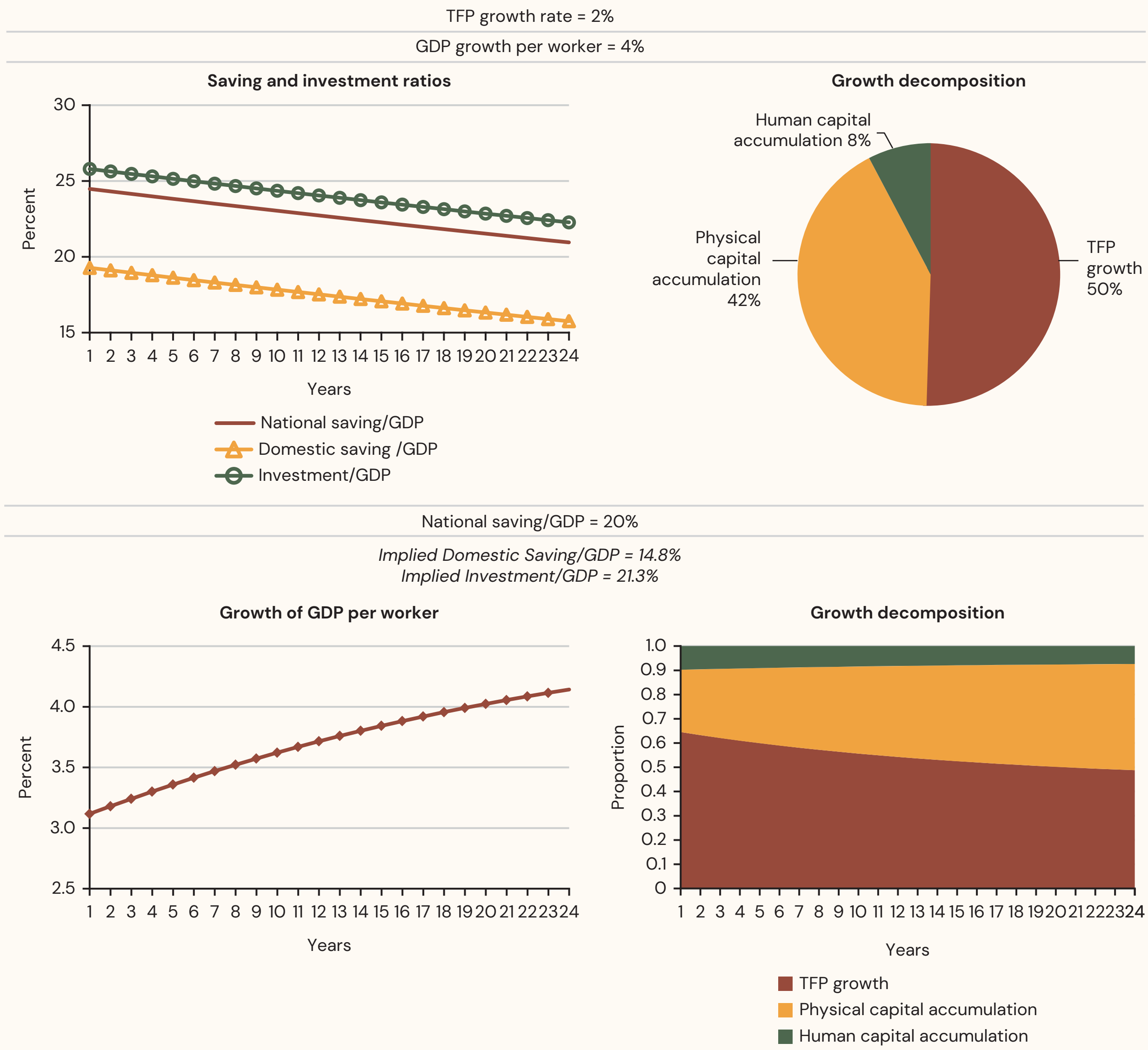
with zero TFP growth). In fact, similar or even larger jumps in national saving have taken place in East Asian countries, most notably China, and have supported their remarkable growth performance.

The second simulation under the moderate scenario shows the behavior of GDP per worker growth when national saving stays at the current level of 20% of GDP. Given TFP growth of 1%, the growth rate of GDP per worker is expected to rise gradually from about 2.1% to 2.4% in the 25 years of the simulation period. In contrast to the case of zero TFP growth, when TFP grows even moderately, the same rate of national saving leads not only to higher but also to increasing GDP per worker growth. TFP growth alleviates the restriction of foreign saving, producing a level of investment rate of 1 percentage point of GDP higher than national saving (and 6 percentage points higher than domestic saving). Moreover, TFP growth reduces the pressure of diminishing capital returns, which combined with higher investment leads to an expansion of the contribution that capital accumulation makes to output growth (see the Solow growth decomposition on the right of the lower panel in figure 9.4).

Finally, let us consider the optimistic case, where TFP grows at a 2% rate (figure 9.5). According to the first simulation (upper panel), the required saving rates to finance a 4% GDP growth per worker is only slightly higher than current averages. National saving would need to rise to about 24% of GDP and then gradually decrease to 21%, meaning that the same growth target can be financed with a lower saving effort over time. As the Solow growth decomposition shows, now one-half the contribution to GDP per worker growth comes from TFP. It is this impulse that relieves the pressure on capital accumulation which can now take second stage on the generation of economic growth.

The second simulation under high TFP growth indicates that GDP per worker growth will start strong and increase even further, from 3.1% to 4.2% in the 25 years of the simulation horizon (figure 9.5. lower panel). This is achieved even while maintaining the national saving rate at the current level of 20% of GDP. As the Solow growth decomposition shows, the contribution of capital accumulation actually grows over time, from about 20% to 40% of economic growth. More strongly than in the moderate case, the growth of TFP allows higher participation of foreign saving (and thus a larger investment rate), produces a higher level of national saving, and alleviates the pressure of decreasing capital marginal productivity.

Figure 9.5: Optimistic Scenario



4. Robustness to Changes in Parameters

The quantitative predictions of our model depend on the calibrated parameter values. In this section we conduct some robustness exercises by changing some parameters that are difficult to measure or subject to controversy. In particular, we consider changes in α, the capital share in output; in δ, the depreciation rate of capital; and in β, the targeted level of foreign liabilities as percentage of GDP. Tables 9.1 and 9.2 present the results of these experiments, along with those corresponding to the benchmark calibration. Table 9.1 displays the national saving rate that is necessary to finance a GDP per capita growth rate of 4 percent under the three scenarios regarding TFP growth. The rows labeled "Baseline calibration" report results of the baseline model. The remaining rows report results of the different calibrations. Likewise, table 9.2 reports projected per capita growth paths when the national saving rate remains fixed at 20 percentage points of GDP.

Consider first the capital share in output. Reliable estimates of α require reliable estimates of national account data on employee compensation. Gollin (2002) and Bernanke and Gürkaynak (2002) argue that, in many developing countries, the series on employee compensation substantially understate the labor share in output because of the large number of self-employed workers or employees working outside the corporate sector. Adjusting these series with complementary data, these authors find that in those countries for which these adjustments can be made, the capital share in output is about one-third, consistent with the values obtained in developed countries.

In our benchmark calibration, the capital share in output α was set equal to 0.5, which is an average of available Egypt-specific estimates. We now check the robustness of our results using $\alpha = 0.35$, a value more aligned with the international evidence cited above. Under the new calibration, the main message of the

Table 9.1: Required Saving Rate to Finance 4% Per Capita GDP Growth (benchmark calibration and parameter variations to check for robustness)

Productivity Growth Scenarios	National saving rate over time (% of GDP)		
	5 years	10 years	25 years
Pessimistic scenario: $\gamma_A = 0\%$			
Baseline calibration	41	48	81
Capital share, $\alpha = 0.35$	57	77	198
Depreciation rate, $\delta = 0.06$	47	55	92
Long-run debt/GDP, $\beta = 0.4$	40	47	79
Moderate scenario: $\gamma_A = 1\%$			
Baseline calibration	32	34	42
Capital share, $\alpha = 0.35$	41	49	81
Depreciation rate, $\delta = 0.06$	37	40	49
Long-run debt/GDP, $\beta = 0.4$	30	33	40
Optimistic scenario: $\gamma_A = 2\%$			
Baseline calibration	24	23	21
Capital share, $\alpha = 0.35$	28	29	31
Depreciation rate, $\delta = 0.06$	29	28	25
Long-run debt/GDP, $\beta = 0.4$	23	22	19

chapter is, in fact, reinforced. Take, for example, the economy with moderate TFP growth in table 9.1. The required national saving rate to finance 4 percent of GDP per capita growth increases to 41 percent in 5 years, 49 percent in 10 years, and 81 percent in 25 years. These rates are substantially larger than those obtained under the baseline calibration. Likewise, table 9.2 shows that when the capital share in output decreases, projected growth rates decrease as well over the next 25 years relative to the baseline calibration. The intuition for this result is as follows: as the capital share in output decreases, the contribution of capital to total output decreases as well. Thus, if growth is to be sustained through capital accumulation alone (instead of productivity growth), investment must increase at a substantially higher rate, inducing a higher burden on domestic saving. The need to increase productivity to achieve growth is even more important when α decreases relative to the baseline calibration.

Consider now the depreciation rate, δ. In the baseline calibration we set $\delta = 0.04$. While this is a standard value, many studies consider higher depreciation rates. We thus study the properties of our model when the annual depreciation rate of capital is 6 percentage points. As above, our results are reinforced with the new calibration. Table 9.1 shows that, for any degree of TFP growth, national saving rates required to finance a growth rate of GDP per capita of 4 percent invariably increase as δ increases from 0.04 to 0.06. Likewise, table 9.2 shows that, given a level of TFP growth, projected per capita GDP growth rates are lower when the depreciation rate increases. In effect, as δ increases, a larger fraction of capital depreciates from year to year. Thus, if GDP growth rates are to remain constant—as the exercises in table 9.1 assume—the investment rate must increase to maintain the same growth rate in the stock of capital. Given TFP, this can be achieved only through an increase in national saving. Likewise, if the national saving rate remains constant, increasing the depreciation rate induces lower capital accumulation, and therefore, a lower GDP per-capita growth (table 9.2).

Table 9.2: Projected Per Capita Growth Rate if Saving Rate Remains at 20% of GDP (benchmark calibration and parameter variations to check for robustness)

Productivity growth scenarios	Per-capita GDP growth rate over time (%)		
	5 years	10 years	25 years
Pessimistic scenario: $\gamma_A = 0\%$			
Baseline calibration	1.0	0.9	0.8
Capital share, $\alpha = 0.35$	0.9	0.8	0.7
Depreciation rate, $\delta = 0.06$	0.0	0.2	0.4
Long-run debt/GDP, $\beta = 0.4$	1.2	1.0	0.8
Moderate scenario: $\gamma_A = 1\%$			
Baseline calibration	2.1	2.2	2.4
Capital share, $\alpha = 0.35$	1.9	2.0	2.1
Depreciation rate, $\delta = 0.06$	1.0	1.6	2.1
Long-run debt/GDP, $\beta = 0.4$	2.3	2.4	2.5
Optimistic scenario: $\gamma_A = 2\%$			
Baseline calibration	3.1	3.6	4.2
Capital share, $\alpha = 0.35$	3.0	3.3	3.5
Depreciation rate, $\delta = 0.06$	2.1	3.0	3.9
Long-run debt/GDP, $\beta = 0.4$	3.4	3.8	4.3

Consider finally an increase in the targeted value of foreign debt as a fraction of GDP, β. In the baseline calibration we chose $\beta = 0.2$ to match historical evidence in Egypt. But 20 percent of GDP of foreign debt is somewhat low based on the international evidence. By increasing the targeted level of debt to GDP ratio, Egypt could reduce the dependence on national saving and rely more on foreign saving to finance its domestic investment. Thus, in the final experiment we assume that β increases from 20 percent of GDP to 40 percent of GDP. While, in effect, a larger fraction of domestic investment can be financed by foreign investors, we find this effect to be quantitatively small. Consider, for example, the moderate TFP growth scenario in table 9.1. While it is true that the required national saving decreases when β doubles, these declines are small: in a 25-year span, the difference between domestic saving rates under the baseline calibration relative to the higher debt calibration never exceeds 2 percentage points. Similarly, if the national saving rate is fixed at 20 percent of GDP (table 9.2), projected growth rates are very similar when compared to those in the baseline calibration.

In summary, we performed a number of robustness checks relative to some parameters that are difficult to calibrate or subject to controversy: the capital share in output, the depreciation rate of capital, and the targeted level of foreign debt to GDP. In all cases, our main message remains intact: a growth agenda based on increasing national saving alone is not sustainable; a successful development strategy requires large and persistent increases in productivity.

5. Conclusions and Policy Implications

With an average per capita GDP growth rate of 3% in the last five decades, Egypt has been in the top 25% of all countries around the world. This remarkable growth performance has been enabled by major private and public investment and, at certain times, by significant productivity gains.[8] This process would not have occurred if national saving had not been up to standards. In fact, Egypt's national saving rate was well above that of the median country in the world on average since the 1960s. However, since the 1990s, Egypt's national saving rate has stopped increasing and has fluctuated around 20% of GDP. For Egypt's high development aspirations to have any plausible chance to be met, a stronger performance is required from both economic growth and national saving.

The objective of this chapter has been to understand the interconnection between saving and growth and the possibilities and limits of a saving-based growth agenda in Egypt. Tables 9.3 and 9.4 summarize the results obtained. Table 9.3 shows the required saving rate to finance a GDP per capita growth rate of 4%, while table 9.4 presents the projected growth rate if national saving rate remains at 20% of GDP.

Table 9.3: Required Saving Rate to Finance 4% Per Capita GDP Growth

Productivity growth	National saving rate (% GDP) overtime		
	5 years	10 years	25 years
0%	41	48	81
1%	32	34	42
2%	24	23	21

[8] For an analysis of total factor productivity in Egypt, see Loayza and Honorati (2007), Favaro, Garrido, and Stucka (2009), and Herrera et al. (2010).

Table 9.4: Projected Per Capita Growth Rate if Saving Rate Remains at 20% of GDP

Productivity growth	Per-capita GDP growth rate over time (%)		
	5 years	10 years	25 years
0%	1.0	0.9	0.8
1%	2.1	2.2	2.4
2%	3.1	3.6	4.2

Our main conclusion is that if the Egyptian economy does not experience progress in productivity—stemming from technological innovation, improved public management, and private-sector reforms—, then a high rate of economic growth is not feasible at current rates of national saving and would require a saving effort that is highly unrealistic. However, if productivity starts to rise to at least moderate levels, sustaining and improving high rates of economic growth becomes viable. For the goal of achieving high economic growth, the national saving effort can realistically only be alleviated by forceful and purposeful productivity improvements.[9]

The following describes selected policy measures and reforms that could be implemented to foster sustained productivity growth in Egypt. These measures broadly fall under the areas of institutional reform and infrastructure provision.

Consider first the privatization of state-owned firms. In 1991, over 300 state-owned firms were identified as candidates for privatization in Egypt (Law 203). Evidence suggests that firms privatized under the new law enjoyed a substantial increase in productivity. In effect, this improvement in productivity was observed with great strength during the 1990s, the period when most of the privatization wave took place: privatized firms increased investment expenditures, profitability, and overall efficiency (Omran 1997). Related to this point is the observation that, historically, a unit of investment by the private sector is almost invariably more productive than a unit of public investment (World Bank 2008). Moreover, there is evidence that non-infrastructure public investment crowds out private investment in Egypt (Fawzy and El-Megharbel 2004). Today, many firms identified by Law 203 as candidates for privatization still remain publicly owned—the privatization wave was temporarily stalled in the late 1990s, but partially resumed in mid-2004. In light of the above evidence—and, more generally, worldwide evidence—it is expected that continuing with the privatization effort is likely to promote significant productivity gains.

An analysis of firm-level data shows that Egypt has experienced substantial progress in labor and total factor productivity between 2004 and 2008 (World Bank 2009). Moreover, the same study reports substantial progress in improving the overall investment climate during these years. In effect, the country experienced significant improvements in the tax code, in customs and tax administration, and in how costly it is to open a new business—in monetary and non-monetary terms. Yet, firms still report macroeconomic and regulatory uncertainty as the main constraints on their operations and growth. Therefore, effort should be devoted in simplifying rules and providing consistent and clear information (see Helmy [2005] for the case of bankruptcy regulation); and in reducing macroeconomic uncertainty, mainly through the consistent and predictable conduct of monetary policy—and, therefore, the management of inflation.

[9] In any case, increasing the national saving rate is still a desirable objective. Hevia, Ikeda, and Loayza (2010) discuss policy measures targeted at increasing national saving independently of productivity.

In addition, more effort should be devoted to improving public infrastructure, preferably through changes in the composition of public expenditures and increased private sector participation (Fawzy and El-Megharbel 2004). In effect, since the mid-1990s infrastructure investment has suffered a substantial decline—mostly due to lower public investment. While the current level of infrastructure in Egypt is what is expected given its national income, the low level of investment is unlikely to sustain the current stock of infrastructure given its natural depreciation and aging. Estimates in Loayza and Odawara (2010) suggest that increasing infrastructure investment from 5 to 6 percentage points of GDP is expected to raise the annual per capita growth rate of GDP by about 0.5 percentage points in the medium term and about 1.0 percentage point in the long run. Moreover, if the increase in infrastructure investment does not imply a heavier tax burden, the increase in growth would be substantially larger. In fact, there is ample room for private sector participation—alone or in partnership with the government—especially in the transport sector (Ragab and Fouad 2009). Because infrastructure and other factors of production complement each other, an increase in infrastructure investment is expected to increase the productivity of physical capital and labor. In effect, in the light of our simple model, an increase in the level of infrastructure is immediately reflected as an increase in total factor productivity. It should be noted, however, that increasing infrastructure investment does not necessarily mean building new roads or new telephone lines. The maintenance and improvement of the current infrastructure should also be amply beneficial.

The model, calibration, and simulation presented in the chapter provide a stylized analytical tool to examine the possibilities and limitations of a saving-based growth agenda. In our view, it focuses on the most relevant issues for the current Egyptian experience. Although it may be applicable to other countries and contexts, various extensions would surely be needed to accommodate specific cases. A richer model would take into account, among other things, the disaggregation of savings into its public and private components and the relationship between the two; the behavioral response of private savings to changes in income, demographic structure, and economic uncertainty; the changing nature of external solvency in the presence of concessional borrowing, international financial shocks, or financial deepening; and the sectoral sources of improvement in total factor productivity. This we leave for future work.

Appendices are available at the journal website: https://doi.org/10.1142/S1793812012500022**.**

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Chapter 10

Saving and Growth in Sri Lanka[1]

Constantino Hevia and Norman V.Loayza[2]

Abstract

In the aftermath of its long-standing civil war, Sri Lanka is keen to reap the social and economic benefits of peace. Even in the middle of civil conflict, the country was able to grow at rates that surpassed those of its neighbors and most developing countries. It is argued, then, that the peace dividend may bring about even higher rates of economic growth. Is this possible? And if so, under what conditions? To be sure, Sri Lanka's high growth rate in the past three decades did not come for free. It took an increasing effort of resource mobilization in the country, with a rise in national saving from 15 percent of gross domestic product in the mid-1970s to 25 percent in 2010. This rise in national saving was fundamentally fueled and sustained by the private sector. In the future, however, the private saving rate is likely to decline because the demographic transition experienced in the country is bound to produce higher old dependency rates in the next two decades. However, the public sector has much room for reducing its deficits and increasing public investment. Similarly, external investors are likely to encounter attractive and profitable investment projects in the coming years in a reformed and peaceful environment. The government of Sri Lanka has two goals regarding these issues. First, increasing public saving to 1.5 percent of gross domestic product by 2013; and second, increasing international investment in the country by letting the current account deficit increase to 4.0–5.0 percent of gross domestic product in the coming years. If these goals are achieved, what can be expected for growth of gross domestic product in the country? To answer this question, this chapter presents a neoclassical growth model with endogenous private saving, calibrates it to fit the Sri Lankan economy, and simulates the behavior of growth rates of gross domestic product and related variables under different scenarios. In what the authors call the reform scenario, total factor productivity would increase from 1.00 to 1.75 percent per year. This would produce a gross domestic product growth rate of about 6.5 percent in the next five years, 4.6 percent by 2020, and 3.5 percent by 2030, the end of the simulation period. This robust growth performance would be supported at the beginning mainly by capital accumulation but later on mainly by productivity improvements.

JEL: O40, O47, E21.
Keywords: Economic growth, private saving, public saving, growth accounting, Sri Lanka.

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[1] **Editors' note:** This chapter is a reprint of World Bank Policy Research Working Paper WPS 6300, originally published in January 2013. This chapter represents the second version of the model that would go on to evolve into the Standard Long Term Growth Model (LTGM) (chapter 1) several years later. As such, the model presented in the chapter differs in notation and substance from the main LTGM of chapter 1. Appendixes are available at the LTGM website: http://www.worldbank.org/LTGM or http://documents.worldbank.org/curated/en/854661468101377762/Saving-and-growth-in-Sri-Lanka. Affiliations are based on when the paper was written, not necessarily current affiliations.

[2] Constantino Hevia and Norman V.Loayza, World Bank. Corresponding author: nloayza@worldbank.org. The views expressed here are the authors', and do not necessarily reflect those of the World Bank, its Executive Directors, or the countries they represent. We are grateful to Francis Rowe, Brian Pinto, and Luis Servén for guidance and support for this project. We thank Mona Prasad and Susana Lundstrom for data and related advice. Tomoko Wada provided excellent research assistance.

1. Introduction

In the aftermath of its long-standing civil war, Sri Lanka is keen to reap the social and economic benefits of peace. Even in the middle of civil conflict, the country was able to grow at rates that surpassed those of its neighbors and most developing countries (see figure 10.1). It is argued that the peace dividend may bring about even higher rates of economic growth. Is this possible? And if so, under what conditions? The key to answer these questions resides in the interaction between Sri Lanka's potential for capital accumulation and the likelihood of strong productivity improvements in the coming years.

Goals to increase economic growth usually refer back to concerns for raising national saving. This is at least partially warranted because the relationship between national saving and economic growth is quantitatively strong and robust to different types of data and methodologies (Mankiw, Romer, and Weil 1992; Attanasio, Picci, and Scurco 2000; and Banerjee and Duflo 2005; among many others). Countries that have high saving rates for long periods of time tend to experience large and sustained economic growth (see figure 10.1). A prime example is the experience of the developing countries in East Asia, such as China, Singapore, the Republic of Korea, Malaysia, Thailand, and Taiwan, China (Young 1995).

To be sure, some of the relationship between growth and saving reflects the positive impact that higher income has on improved saving (Loayza, Schmidt-Hebbel, and Serven 2000). However, no less important is the causality that runs from higher saving to larger growth, where the mechanism resides on the well-known process of capital accumulation. Improved national saving provides the funds to take advantage of more and larger investment opportunities. This, in turn, increases the capital stock, which effectively used for economic production contributes to higher output growth. Although in theory domestic investment does not have to be supported by national saving, in practice the connection between the two is quite close (Aizenman, Pinto, and Radziwill 2007). This is especially true in the long run, when external sources of funds can be tapped only in a restricted manner: large current account deficits cannot be sustained indefinitely. This is exemplified by the strong relationship between the average saving and investment rates across countries in the last three decades, as depicted in figure 10.2.

In Sri Lanka, as in most other countries, capital accumulation depends crucially on the country's ability to save. National saving in Sri Lanka increased from below 15% of GDP in the mid-1970s to about 25%

Figure 10.1: Saving and Growth

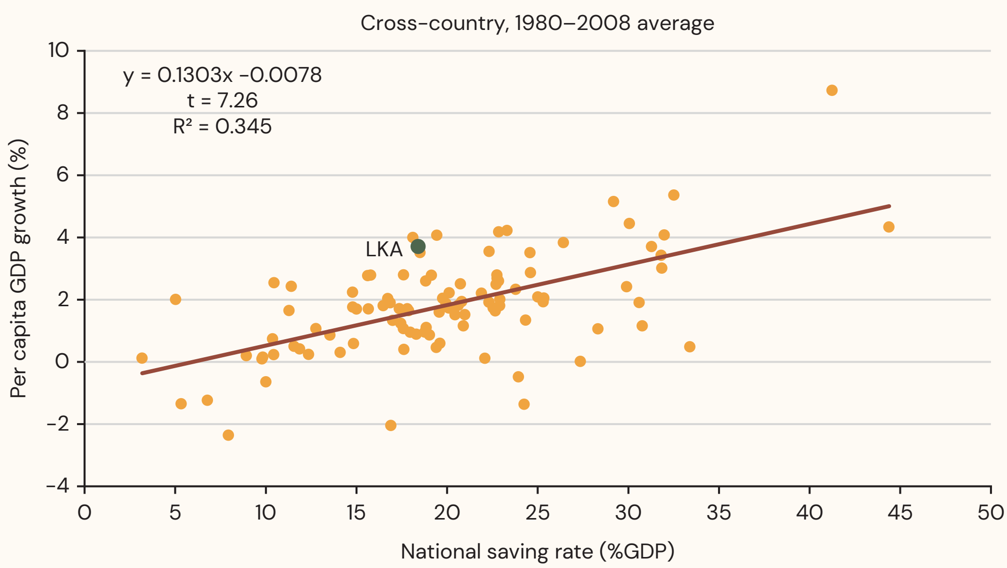
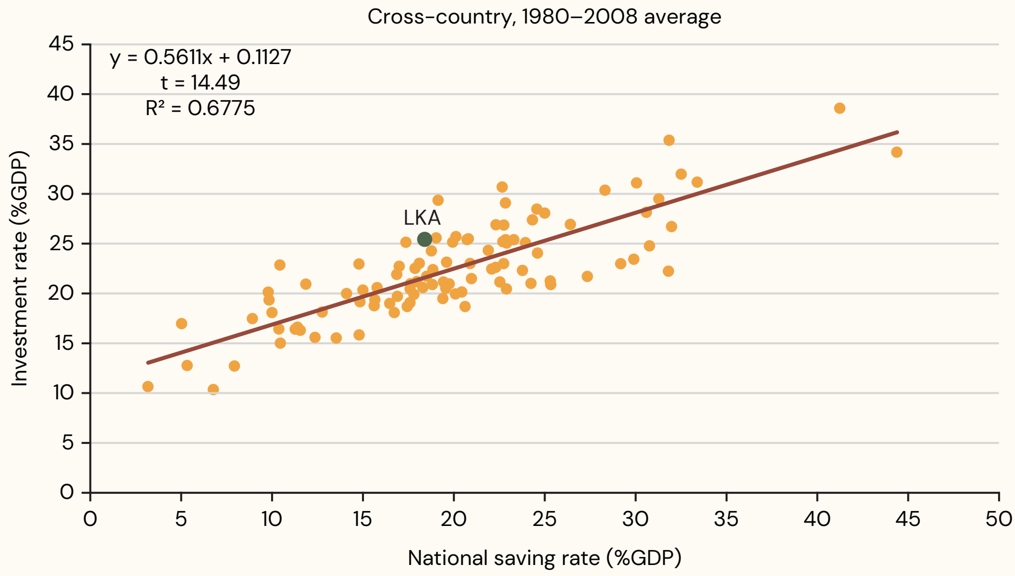


Figure 10.2: Saving and Investment



of GDP in 2010 (see figure 10.3). This is a remarkable trend. However, it is the private sector which has supported this positive trend, while the public sector has decreased its savings since the mid-1980s, even dissaving since the 1990s.

Most national savings in Sri Lanka have originated from income inside the country. From the mid-1980s, domestic savings have been 75–80% of national saving (see figure 10.4). A non-negligible share, however, has originated from income from abroad. Official grants were the majority of foreign income in the late 1970s and early 1980s, while workers' remittances increased from almost nothing in the mid-1970s to 5% of GDP by the early 1980s. Since then, workers' remittances have remained in the range of 5 to 7% of GDP, explaining the majority of the difference between national and domestic saving.

Figure 10.3: National, Private, and Public Saving in Sri Lanka

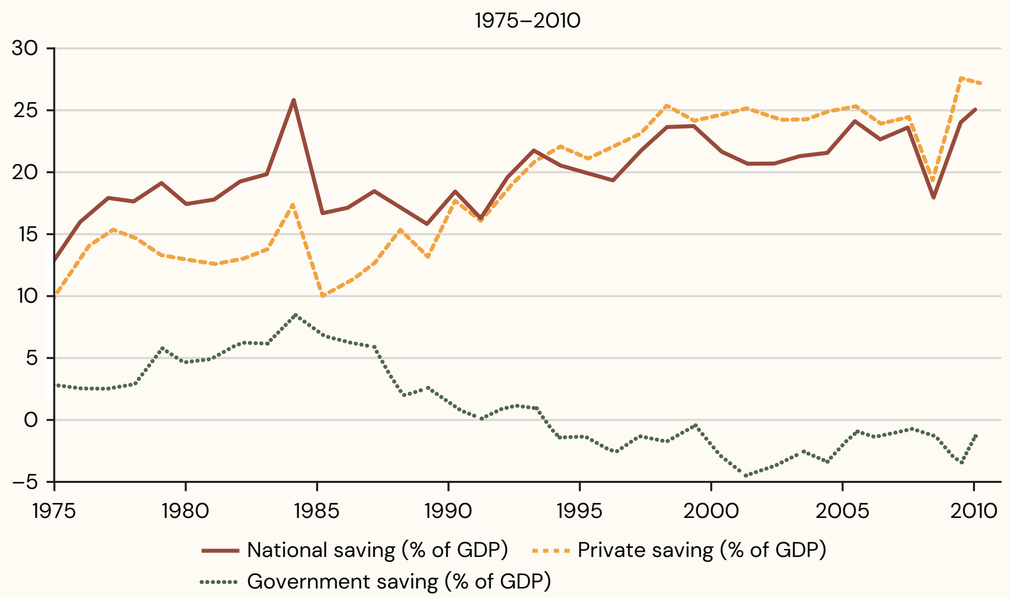
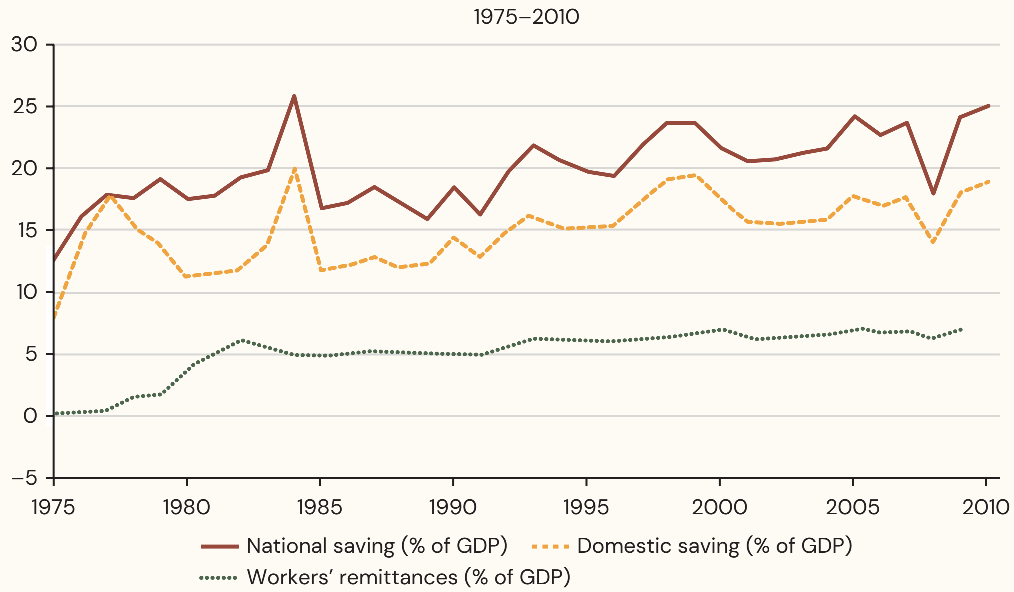


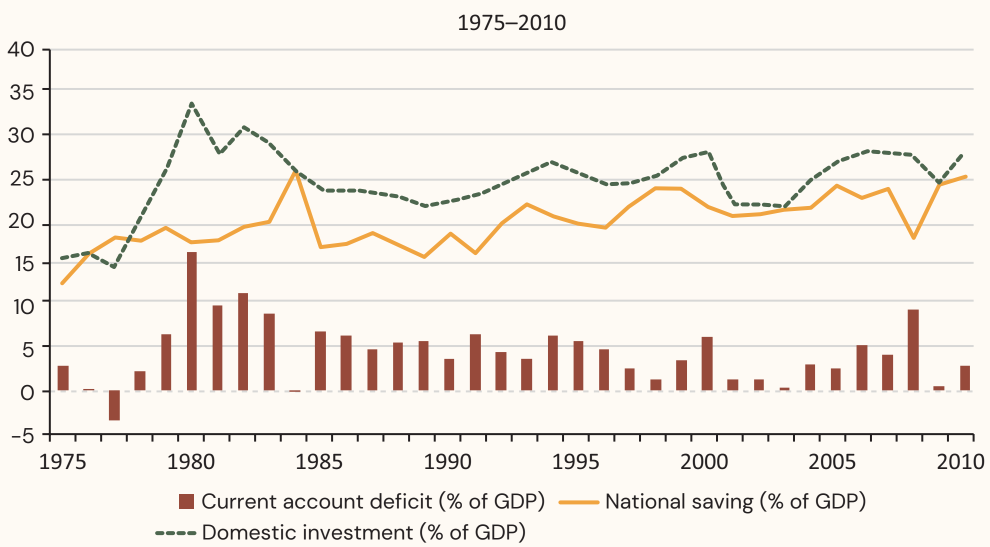
Figure 10.4: National and Domestic Saving in Sri Lanka



In Sri Lanka, the domestic investment rate has been traditionally higher than the national saving rate, with a resulting sustained current account deficit (see figure 10.5). Except for a few years in the early 1980s when the current account deficit jumped as high as 16% of GDP, it has remained at around or below 5% of GDP. The inflow of resources from abroad has helped the country maintain higher rates of growth than its national saving rate alone would have predicted (see figure 10.1). Although foreign financing is expected to continue in the future, it is likely to remain within the confines of its historical rates with respect to economy's size.

The links in the relationship between saving and growth are not mechanical but depend on the quality of the financial system and public institutions in general. Without an efficient financial system, the best investment opportunities will not be matched with the available saving (Levine 2005). Likewise, without proper public institutions (that guarantee macroeconomic stability and contract enforcement, for instance), accumulated capital may remain idle or ineffectively used (Hall and Jones 1999; Easterly

Figure 10.5: National, Private and Public Saving in Sri Lanka



and Levine 2001). This points to the crucial importance of the efficiency or productivity with which physical capital, human capital, and labor are used in the production process. The growth of factor productivity is what in the end determines whether a saving and investment effort will result (or not) in improved economic growth.

The objective of this study is to illustrate the mechanisms linking national saving and economic growth in Sri Lanka. Moreover, recognizing that private saving is not directly a policy lever but an endogenous variable, the study will assess the role and potential contribution of public saving in generating growth. We will do this through a simple theoretical model, calibrated to fit the Sri Lankan economy, and simulated to explore different potential scenarios. Our goal is to understand the two-way connection between saving and growth and the possibilities and limits of a saving-based growth agenda, in the context of Sri Lanka's economy.

An optimality of saving behavior can be posed from different angles. The most common in the academic literature is the perspective of optimal saving as the behavior that maximizes a consumer welfare function. This, however, may be too abstract for the needs and objectives of policy practitioners. For this reason, we pose the problem of optimal saving from the perspective of financing a given rate of economic growth while simultaneously achieving external sustainability.

The chapter proceeds as follows. First, we present a simple model, constructed with the purpose of understanding the necessary level of national and public saving to generate a given rate of economic growth (that is, following the optimality perspective described above). The model is neoclassical in the sense that the factors of production—labor and physical and human capital—are subject to decreasing marginal returns. Had we used instead an endogenous growth model with constant marginal returns to capital, changes in the rate of capital accumulation would have had permanent effects on long-run growth, a result not supported by the evidence (Bernanke and Gürkaynak 2002; Caselli 2005; Easterly and Levine 2001; Hall and Jones 1999). Moreover, methodologically it is more straightforward to examine both the limitations of a saving-based growth agenda and the role of productivity improvements in the context of the neoclassical model than the endogenous growth model.

Second, we calibrate the model to Sri Lanka's economy, using parameters and relationships obtained in the received literature for the country. Third, using the calibrated model, we perform some simulations that clarify the relationship between public and national saving, productivity, and growth, allowing us to discuss policy options for improving economic growth in Sri Lanka. And fourth, we provide some concluding remarks, arguing that for the country to grow at rates comparable to those of the East Asian tiger economies, the public sector must contribute substantially to national saving, and institutional and economic reforms must lead to strong and persistent productivity improvements.

2. A Simple Model

We consider a model of an open economy with a single sector that produces a unique final good which we call gross domestic product (GDP) or, simply, output. The economy evolves in discrete time and each time period, denoted by an index t, represents one year.

The economy has access to a technology to produce output by combining capital and labor inputs according to the production function

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{1}$$

Where Y_t denotes output, K_t is the stock of physical capital, L_t denotes the labor input, A_t is a measure of the level of total factor productivity (TFP) of capital and labor, and the technology parameter $\alpha \in (0, 1)$

measures the relative contribution of capital to the production of output—in an economy operating under perfect competition, α measures the share of output distributed as payments to capital.

We abstract from distributional issues and assume that all workers have the same level of human capital. Following Bils and Klenow (2000) and Hall and Jones (1999), we assume that each worker has been trained with z_t years of schooling, which deliver a productivity of exp (ϕz_t) efficiency units of labor per worker, where exp(.) denotes the exponential function. Thus, ϕz_t measures the relative efficiency of a worker with z_t years of schooling relative to one with no schooling. Thus, if we let E_t denote the working-age population, effective aggregate labor supply is given by

$$L_t = \exp(\phi z_t)E_t. \tag{2}$$

Capital depreciates at a constant rate δ per year, but can be augmented through investment. Namely, the stock of capital evolves according to

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{3}$$

where I_t denotes aggregate investment.

Abstracting from valuation changes, the current account deficit at period t, CAD_t, is defined as the change in net foreign liabilities of the whole economy, or

$$CAD_t \equiv B_{t+1} - B_t = rB_t + C_t + G_t + I_t - Y_t - TR_t, \tag{4}$$

where B_t is the stock of net foreign liabilities due at period t; r is the world interest rate, assumed constant for simplicity; C_t denotes private consumption; G_t denotes government consumption expenditures; and TR_t denotes the flow of net external current transfers (worker remittances and official grants) that are not reflected as changes in the country's net foreign liabilities.[3]

If we let $S_t^N = Y_t + TR_t - rB_t - C_t - G_t$ denote aggregate national saving, equation (4) can be rearranged into the familiar investment-saving gap identity of an open economy,

$$I_t = S_t^N + CAD_t. \tag{5}$$

That is, domestic investment I_t can be financed through national saving or through foreign saving (i.e., through an increase in net foreign liabilities).

External solvency requires that the current value of foreign liabilities be no larger than the present value of net exports, and can be obtained by iterating forward on the current account identity, equation (4), namely,

$$\sum_{j=0}^{\infty}\frac{1}{(1+r)^j}\left[Y_{t+j} + TR_{t+j} - I_{t+j} - C_{t+j} - G_{t+j}\right] = (1+r)B_t.$$

This solvency condition imposes certain assumptions about the functioning of international capital markets that are difficult to reconcile with the experience of emerging market economies. In particular, it fails to capture the financial frictions that are pervasive in developing countries. For this reason, we follow Milesi-Ferretti and Razin (1996) and impose a sufficient condition for current account sustainability that is also appealing in terms of its realism.

In Hevia and Loayza (2011) we assumed that the economy was required to maintain the ratio of net foreign liabilities to GDP constant. For the case of Sri Lanka, this might be too strong an assumption, given

[3] Worker remittances and other transfers from abroad are quite important for Sri Lanka, representing over 5% of GDP in the last decade.

expectations of larger foreign participation in domestic investment during the next years. We thus assume that the ratio of net foreign liabilities to GDP is allowed to evolve through time according to,

$$B_t/Y_t = \beta_t \tag{6}$$

where $\{\beta_t\}$ is an exogenous sequence. For example, if β_t increases for a number of years and then becomes constant, the economy is increasing its foreign indebtedness and, thus, the foreign participation in domestic capital formation. On the other hand, if β_t decreases through time, the economy is reducing its foreign indebtedness. The proposed modification to the solvency condition is a reduced form approach aimed to capture the reluctance of foreigners to lend money when the level of debt is sufficiently high, or because the government wants to maintain a safe level of foreign borrowing relative to output.

Using the definition of the current account, equation (6) imposes the following restriction on the current account deficit as a fraction of gross domestic output,

$$\frac{CAD_t}{Y_t} = \frac{B_{t+1}}{Y_{t+1}}\frac{Y_{t+1}}{Y_t} - \frac{B_t}{Y_t} = \beta_{t+1}\frac{Y_{t+1}}{Y_t} - \beta_t. \tag{7}$$

That is, the ratio of the current account deficit to the value of output depends upon the net foreign liabilities as a fraction of GDP at times t and $t + 1$, and on the growth rate of output, Y_{t+1}/Y_t.

For quantitative purposes, we find it convenient to rewrite all previous equations in per capita terms. To that end, let N_t denote total population at time t and, for any aggregate variable X_t, let $x_t = X_t/N_t$ denote the corresponding variable in per capita terms. Thus, introducing the definition of effective labor, equation (2) into the production function, equation (1) and dividing the resulting expression by N_t gives the following expression for GDP per capita:

$$y_t = A_t k_t^{\alpha}\left(\exp(\phi z_t)e_t\right)^{1-\alpha}. \tag{8}$$

In general, the labor force variable $e_t = E_t/N_t$ varies through time as the demographic characteristics of the economy changes.

Following the same approach, we write the equilibrium equations (3), (5), and (7) in per capita terms as

$$k_{t+1}\,\Gamma_{N,t+1} = (1-\delta)k_t + i_t, \tag{9}$$

$$i_t = s_t^N + cad_t, \tag{10}$$

$$\frac{cad_t}{y_t} = \beta_{t+1}\,\Gamma_{y,t+1}\,\Gamma_{N,t+1} - \beta_t \tag{11}$$

Here and throughout the chapter, expressions like $\Gamma_{x,t+1} = x_{t+1}/x_t$ denote the gross growth rate of any variable x_t between periods t and $t + 1$.

We now use the previous equations to write a condition that relates national saving and growth. First, we use the production function in equation (8) at periods t and $t + 1$ to write the gross growth rate in output per capita as

$$\Gamma_{y,t+1} = \Gamma_{A,t+1}\,\Gamma_{k,t+1}^{\alpha}\left(\exp\left[\phi\left(z_{t+1}-z_t\right)\right]\Gamma_{e,t+1}\right)^{1-\alpha} \tag{12}$$

That is, the growth rate of output per capita $\Gamma_{y,t+1}$ depends upon the growth rate of productivity $\Gamma_{A,t+1}$, the growth rate of the stock of capital, $\Gamma_{k,t+1}$ the growth rate of human capital $\exp[\phi\,(Z_{t+1} - Z_t)]$, and the growth rate of the labor force $\Gamma_{e,t+1}$.

Second, introducing the investment-saving equation (10) into the capital accumulation equation (9) and rearranging gives

$$\Gamma_{k,t+1}\,\Gamma_{N,t+1} = 1-\delta+\frac{i_t}{y_t}\frac{y_t}{k_t} = 1-\delta+\left(\frac{s_t^N+cad_t}{y_t}\right)\frac{y_t}{k_t}.$$

This equation describes the growth rate of the stock of capital per person as a function of the growth rate of the population $\Gamma_{N,t+1}$, the depreciation rate δ, the national saving ratio with respect to GDP s_t^N/y_t, the current account deficit as a fraction of GDP cad_t/y_t, and the degree of capital intensity in the economy k_t/y_t.

Imposing the sustainability equation (11) into the last equation, the evolution of the stock of capital becomes

$$\Gamma_{k,t+1}\,\Gamma_{N,t+1} = 1-\delta+\{\sigma_t+\beta_{t+1}\Gamma_{y,t+1}\Gamma_{N,t+1}-\beta_t\}\frac{y_t}{k_t}, \tag{13}$$

where $\sigma_t = s_t^N/y_t$ denotes the national saving ratio with respect to GDP.[4]

Finally, introducing equation (13) into the output growth equation (12) delivers an equation that links the growth rate of output per capita to the national saving ratio σ_t, the growth rate of productivity Γ_{At}, the growth rate of the population Γ_{Nt}, the growth rate of the labor force Γ_{et}, the growth rate in human capital $\exp[\phi(z_{t+1}-z_t)]$, and the capital-output ratio k_t/y_t,

$$\Gamma_{y,t+1} = \left[\frac{1-\delta+\{\sigma_t+\beta_{t+1}\Gamma_{y,t+1}\Gamma_{N,t+1}-\beta_t\}\dfrac{y_t}{k_t}}{\Gamma_{N,t+1}}\right]^{\alpha}\Gamma_{A,t+1}\left(exp\left[\phi\left(z_{t+1}-z_t\right)\right]\Gamma_{e,t+1}\right)^{1-\alpha}. \tag{14}$$

Equation (14) is the key equation that associates the growth rate of GDP per capita with the national saving ratio σ_t

2.1 Endogenous Private Saving

In the previous section we derived an equation that associates national saving with the growth rate of GDP per capita. The question remains, of course, as to how to actually achieve the desired level of national saving given the policy instruments that the government has access to. Any attempt to answer this question faces the immediate fact that private saving is not invariant to policy interventions and to the structural characteristics of the economy, like the ratio of old age and young age populations over the working-age population, the level and growth rate of income, and the level of public saving—capturing Ricardian effects on aggregate saving. A standard way of tackling this problem is to posit a model of intertemporal consumption choice and evaluate how different policies affect the level of private saving. This approach, however, is not free of problems and requires a detailed description of the economic environment, preferences, the set of policy instruments available to the government, and how expectations about future events are formed. To simplify matters and to keep the discussion as straightforward as possible, we follow a different route and consider a reduced form of equation for the private saving rate. Borrowing from Loayza, Schmidt-Hebbel, and Serven (2000), we assume that the private saving rate depends on its own lagged value, on the old age and young age dependency rates, on the level and growth rates of GDP, and on public saving. Loayza, Schmidt-Hebbel, and Serven (2000) contain a detailed discussion about these determinants of

[4] Note that s_t^N/y_t is neither the national saving rate nor the domestic saving rate as defined in the national accounts statistics. The national saving rate is defined as s_t^N/y_t^N where $y_t^N = y_t - rb_t + tr_t$ is national disposable income (per capita), whereas the domestic saving rate is defined as s_t^D/y_t, where $s_t^D = y_t - c_t - g_t$ is domestic saving (per capita).

saving and provide estimates of the aforementioned reduced form private saving equation based on a large cross-section, time-series data set.

We decompose the national saving ratio as the sum of the private and public saving ratios, σ_t^p and σ_t^g, respectively, or

$$\sigma_t = \sigma_t^p + \sigma_t^g. \tag{15}$$

The functional form of the private saving rate at time t is assumed to be,

$$\sigma_t^p = \zeta_1 \sigma_{t-1}^p + \zeta_2 \sigma_t^g + \zeta_3 \log y_t + \zeta_4 \log y_{t-1} + \zeta_5 od_t + \zeta_6 yd_t + \eta,$$

where od_t denotes the old age dependency rate, yd_t is the young age dependency rate, and ζ_i, = 1,…,6 and η are constants. Thus, the private saving ratio depends on its own lagged value, on the public saving rate, on the current and lagged (log) levels of GDP per-capita, and on the old age and young age dependency rates. The parameters ζ_i, = 1,…,6 are set according to Loayza, Schmidt-Hebbel, and Servén's (2000) estimates. The constant η is a country-specific fixed effect which will be removed by differencing the previous equation. In particular, lagging the previous equation and taking the difference gives

$$\sigma_t^p = \sigma_{t-1}^p + \zeta_1 \Delta\sigma_{t-1}^p + \zeta_2 \Delta\sigma_t^g + \zeta_3 \Delta \log y_t + \zeta_4 \Delta \log y_{t-1} + \zeta_5 \Delta od_t + \zeta_6 \Delta yd_t.$$

Inserting this equation into (15) gives the national saving ratio at time t as a function of the public saving ratio at time t, the structural characteristics of the economy, and lagged private saving ratios,

$$\sigma_t = \sigma_{t-1}^p + \zeta_1 \Delta\sigma_{t-1}^p + \zeta_2 \Delta\sigma_t^g + \zeta_3 \Delta \log y_t + \zeta_4 \Delta \log y_{t-1} + \zeta_5 \Delta od_t + \zeta_6 \Delta yd_t + \sigma_t^g. \tag{16}$$

In the quantitative section of the chapter we perform two sets of experiments. In the first experiment, we find the public saving rate required to achieve a certain growth rate of GDP per capita, recognizing that the private saving rate evolves endogenously as a function of the characteristics of the economy. In the second experiment, we fix a path for the public saving ratio and let the private saving ratio and GDP per capita evolve endogenously through time. These exercises are described in detail after we discuss the calibration of the parameters of the model and the estimation of the demographic characteristics of the economy based on data from Sri Lanka.

2.2 Calibration

Before we can use the model to simulate potential scenarios, we need to calibrate it with information specifically related to Sri Lanka's economy. The main pieces of information are the following:

- The current capital-output ratio: k_t/y_t = 1.314. This is the ratio estimated for the year 2010, using a perpetual inventory method to accumulate investment in order to produce a measure of the capital stock. Given the war-related destruction of factories, transport facilities, buildings, and other forms of capital, we cannot assume a fixed and relatively low depreciation rate (0.04– 0.08, as in most of the literature). We allow the depreciation rate to vary and, in order to identify it, assume a constant rate of TFP growth equal to 0.0107, the average reported for Sri Lanka in the last decades by Jorgenson and Vu (2005), Collins (2007), and Son (2010).[5]
- The capital share in output: $\alpha = 0.35$. This is the average across countries that Bernanke and Gürkaynak (2002) obtain using adjusted factor payment data from national accounts. There is no comparable Sri Lanka-specific estimate for the capital share.

[5] On the importance of considering a different depreciation rate for Sri Lanka when estimating the capital stock, see Duma (2007).

- The annual capital depreciation rate: δ = 0.08. This is the depreciation rate used in Klenow and Rodríguez-Clare (2005) in their chapter of the *Handbook of Economic Growth*. It is a bit larger than the depreciation rate assumed in other cross-country studies (e.g., 0.06 in Caselli, 2005). We use this higher rate because it is similar to the average depreciation rate for Sri Lanka in the last few years (after the civil war ended) as obtained in the process of estimating the capital stock (see above).
- The annual growth rate of the labor force, Γ_{Et}, is obtained from the future demographic projections for Sri Lanka population ages 15–70, presented in United Nations (2011), *World Population Prospects: The 2008 Revision*.
- The annual increase in education: $(z_{t+1} - z_t)$ = 0.05104. Education is proxied by the average number of schooling years in the adult population. This estimate for the annual increase in schooling is taken from an updated version of the Barro and Lee (2001) data set and corresponds to the average annual change for the period 1990–2010.
- The annual rate of return to education: ϕ = 0.07. This rate of return is used in Bernake and Gurkaynak (2002) and Collins (2007) in their growth accounting exercises, which also consider the average number of schooling years in the adult population as the proxy for education (and human capital in general).
- The ratio of net foreign liabilities to GDP, β_t, is assumed to rise from its current value of 0.45 to 0.60 gradually in 15 years. This approximately corresponds to the government's target of a current account deficit of 4–5% of GDP over the next five years and declining afterwards. The current ratio of net foreign liabilities to GDP is obtained from updating the Lane and Milesi-Ferreti (2007) database. The Official "international investment position" for Sri Lanka is not available in the International Monetary Funds' (IMF's) Balance of Payments Statistics.
- *Productivity scenarios.* A key parameter in the simulations presented below is the rate of growth of total factor productivity, Γ_{At}. The available estimates for TFP growth in Sri Lanka indicate an average of around 1.00% growth per year in the last few decades (Jorgenson and Vu 2005; Collins 2007; and Son 2010). We consider this TFP growth rate in a first scenario, which we call "continuity scenario". If Sri Lanka is able to reform its economy and institutions along the lines proposed in recent government plans, the country's TFP growth rate is likely to increase substantially. For the second scenario, we use the average TFP growth rate of the top quarter of countries in a worldwide sample as a benchmark for what is possible under economic reform (Bernanke and Gürkaynak 2002). This is approximately equal to the 1.75% per year rate which we use for what we call the "reform scenario." Finally, if Sri Lanka is able to conduct all of its intended reforms and also benefit from a positive international environment, its TFP growth rate could increase even further. We use the rate of 2.50% per year in an "optimistic scenario." This is clearly an upper limit, which very few countries have been able to obtain in a sustainable manner.

3. Simulations

Using the model developed above and the calibration parameters, we can perform different numerical exercises to give answers and insights regarding the links between saving, investment, productivity, and growth. We perform two basic, complementary simulations. The first one is designed to measure the saving rates that are required to finance a given rate of economic growth. This rate is set to 7.2% of GDP per capita growth for the period 2011–2015. This corresponds closely to the government's target GDP growth rate of 8.0% for the next five years. After this period, economic growth is determined by the dynamics of the model. This target growth rate is clearly ambitious from historical and cross-country perspectives for Sri Lanka. The second simulation changes perspectives and asks what economic growth rates can be financed if the public saving rate is increased to a given level. In accordance with government plans, the public saving rate is assumed to increase gradually from its current level of –2.0% of GDP to 1.5% by 2013, and stay constant from then onwards. This implies a reduction in the government deficit to 5.0% of GDP and an increase in public investment to 6.5% of GDP by 2013. In both simulations, private saving is allowed to change endogenously in response to changes in public saving, demographic characteristics, and income growth.

Both simulations are dynamic in the sense that they follow the evolution of the economy for an extended period of time, chosen to be 20 years in our case. Also in both cases, we compute the corresponding Solow growth decomposition in order to understand the role played by factor accumulation and productivity advances in the process of economic growth. As mentioned in the previous section, the simulations are performed under three scenarios regarding the behavior of total factor productivity. TFP growth is assumed to be 1.00%, 1.75%, and 2.50%, and the corresponding scenarios are labeled, Continuity, Reform, and Optimistic, respectively. The basic simulation results are presented in figures 10.6–10.8. In each of them, the upper panels correspond to the simulation where the growth rate of GDP per worker is the target; and, conversely, the lower panel shows the simulation where the public saving rate is set to a given level. In turn, in each panel we show three graphs: the first contains the projected national, public, and private saving rates (with respect to GDP) annually for the period 2010–2030; the second shows the projected annual per capita and aggregate GDP growth rates for the same period; and the third presents a Solow growth decomposition for the years 2011–2016, showing the percentage of contributions of physical capital accumulation, total factor productivity, and labor (including human capital and labor force).

We first discuss the continuity and optimistic scenarios to highlight how the saving-growth relationship changes as productivity growth differs radically. We then present the Reform scenario. We do it in greater depth than in the previous two cases because, in our perspective, it represents the most reasonable situation under a feasible set of international conditions and, most importantly, internal reforms.

Let us then start with the continuity scenario (figure 10.6). The first simulation (upper panel) shows that, in the absence of a substantial improvement in TFP growth, the demands on capital accumulation to attain the goal of 7.2% GDP per capita growth (8.0% GDP growth) in the next five years are excessively large. In fact, as the growth decomposition indicates, more than 80% of GDP per capita growth would have to be supported by physical capital accumulation. The national saving rate would have to increase enormously from 25% to 50% of GDP, requiring a rise in public saving to over 30% of GDP and even further in the course of the twenty-year horizon. The private saving rate would decrease by more than one-half, in part as a reaction to the large increase in the public saving rate.

The second simulation shows that if the public saving rate is increased to 1.5% of GDP, GDP growth would be above 6.0% only in the first years and then decrease gradually to about 4.5% by 2015 and a bit over 2.0% by 2030. The lion share of the contribution to GDP growth (76%) in the next five years would be given by capital accumulation. Given the impulse of public saving, the national saving rate would increase and remain above its current value for the next seven to eight years but would then decrease following the declining trend of private saving. Continuity in TFP growth thus implies a rate of economic growth that, although respectable by international standards, is far below the ambitious targets for the country.

In the other extreme, let us consider the optimistic scenario, where TFP grows at a 2.5% rate (figure 10.7). According to the first simulation (upper panel), in order to finance a 7.2% GDP growth per capita (8.0% GDP growth) in the next five years, national saving would need to rise from 25 to 33% of GDP. In turn, this would require an increase in public saving to almost 10% of GDP by 2015. This would entail a strong effort, but a feasible one at that. As the Solow growth decomposition shows, now TFP would contribute about 35% to GDP per capita growth. The large impulse from TFP under this scenario relieves the pressure on capital accumulation substantially to attain the high target of economic growth.

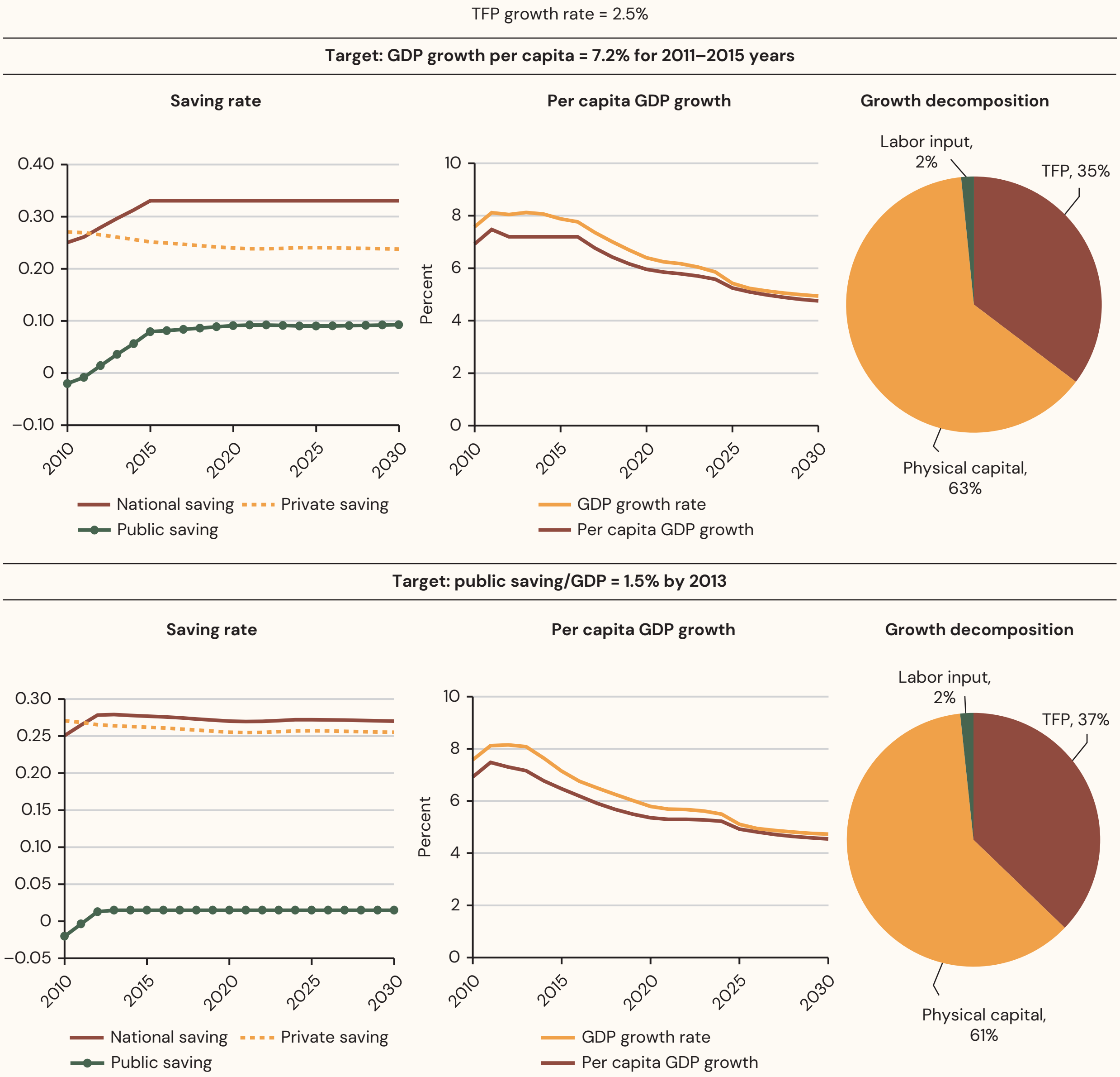
The second simulation under the optimistic scenario indicates that, with a small improvement in public saving, GDP growth would average 8% in the next few years and stay over or around 7% for the next decade. Then, it would decline to about 5% by 2030, the end of our simulation horizon. With the impulse

Figure 10.6: Continuity Scenario

of public saving, the national saving rate would increase to around 27%, and private saving would decrease only slightly. As the Solow decomposition shows, the contribution of TFP growth would account for 37% of GDP growth in the next five years.

Let us now turn to the reform scenario, where TFP grows at a constant annual rate of 1.75% (figure 10.8). The first simulation indicates that achieving a target of GDP per capita growth rate of 7.2% (8.0% GDP growth) in the next five years is indeed a difficult goal. It would require a jump in national saving from the current 25% to about 40% of GDP by 2015, which in turn would require public saving to rise to 20% of GDP. The lion share of the contribution to growth would still need to come from capital accumulation, with only one-fourth coming from TFP growth. The required increase in national saving is substantial but has been observed in East Asian countries, most notably China. With free and endogenously determined private saving, however, the needed increase in national saving would have to be supported by an incredibly large expansion of public saving.

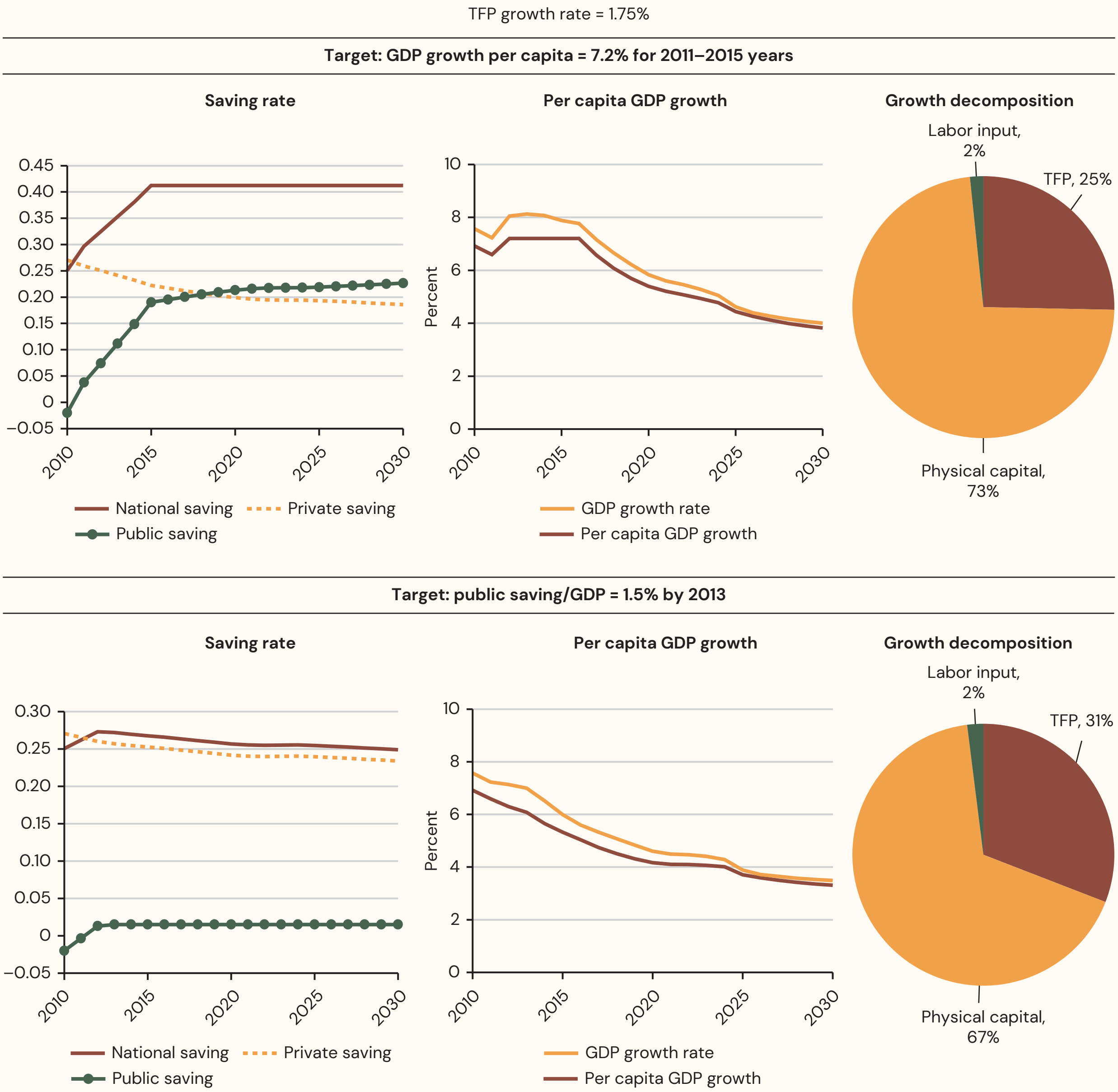
Figure 10.7: Optimistic Scenario



The second simulation under the reform scenario (figure 10.8) shows the behavior of GDP growth if the public saving rate is increased to 1.50% of GDP by 2013. Given TFP growth of 1.75%, the growth rate of GDP would stay around 7.0% in the next five years and then gradually decline to 4.5% by 2020 and 3.5% by the end of the simulation period. Note that the difference between GDP growth and per capita GDP growth diminishes over time as population growth approaches zero.

Given the impulse in public saving, the national saving rate would increase from 25% to 27% by 2013 and then slowly decline back to 25% by 2030. In turn, the private saving rate would follow a secular, though slow, decrease from 27% to 23% of GDP by the end of the simulation period. The trend in the private saving rate is due to the combination of three significant forces. The first is the increase in public saving, which would generate a small compensating decline in private saving. The second is the expected substantial rise in the old dependency rate, which would lead to a gradual fall in the private saving rate. (The expected decrease in the young dependency rate would have the opposite effect but its magnitude is much smaller.) The third

Figure 10.8: Reform Scenario

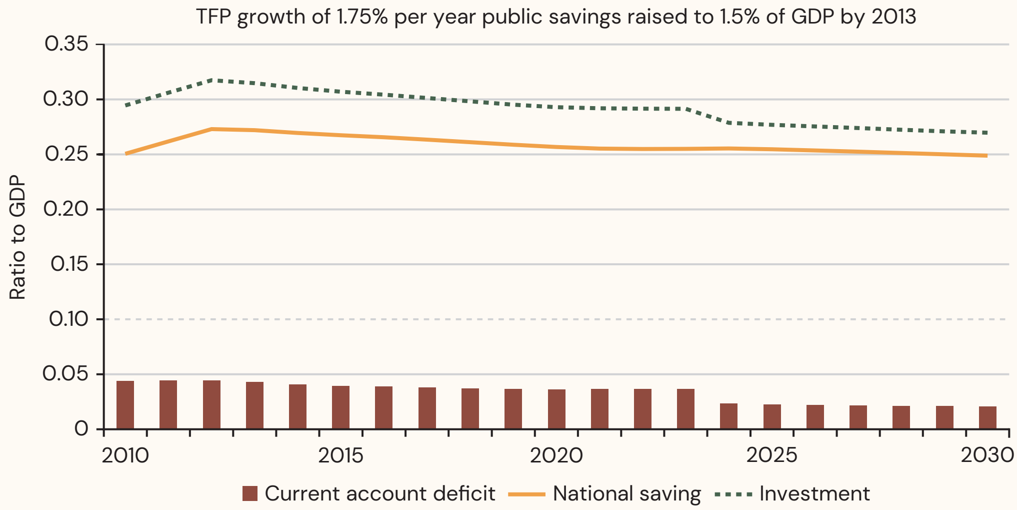


is the rise in income related to GDP per capita growth; this would produce an increase in the private saving rate. It seems, then, that the first two negative forces win over the last one, generating the decline, albeit slow, in the private saving rate.[6]

The behavior of the national saving rate would be followed to some extent by the rate of domestic investment (figure 10.9). Domestic investment would rise during the next few years, prompted by the rise in public and national savings, and then decline gradually. The difference between saving and investment, that is, the current account deficit, would be close to 5% of GDP in the next 5 years and then decline to about 2% by the end of the simulation period. The larger initial current account deficit is consistent with the assumed increase in net foreign liabilities from 45% to 60% of GDP in the next 15 years.

[6] The variation in the slope across simulations and scenarios is related to the projected change in public saving and GDP growth. The effect of demographic factors is constant across simulations and scenarios.

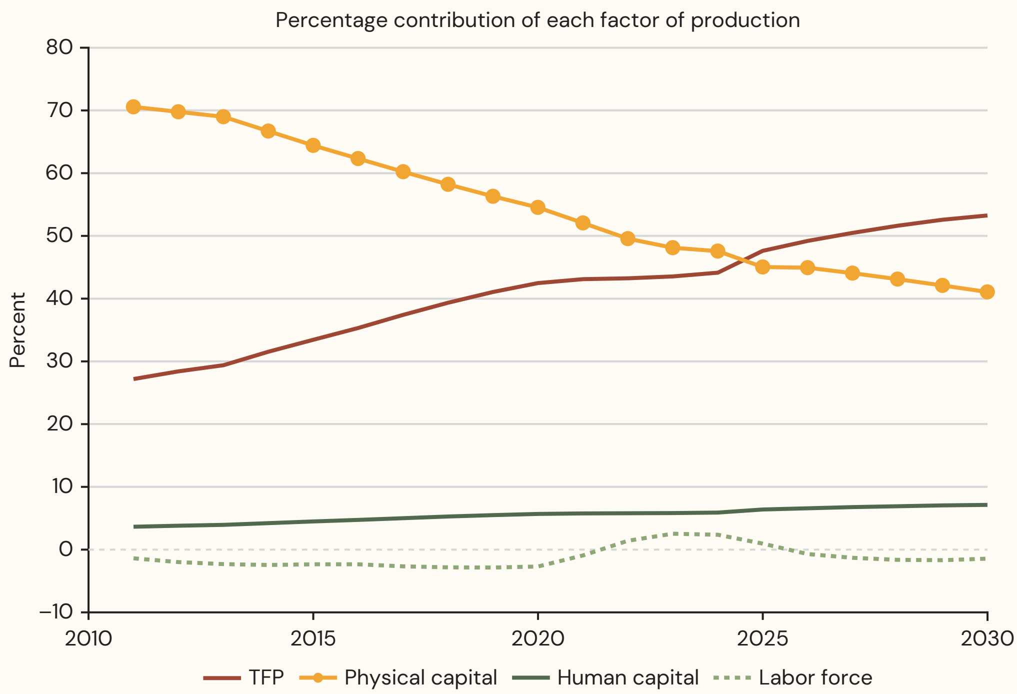
Figure 10.9: Saving, Investment, and the Current Account under the Reform Scenario



Source: Authors' calculations

The Solow decomposition presented in figure 10.8 indicates that in the next five years, physical capital accumulation would account for 65% and TFP improvements for about 30% of GDP growth. The relative contribution of the factors of production to economic growth would not be constant over time, however. It would change over the course of the simulation period, as shown in figure 10.10. As noted before, in the first years capital accumulation would contribute by far more than any other production factor to economic growth. However, its relative contribution would decline as the capital stock grows and, therefore, faces diminishing returns. Over the course of the simulation period, the capital-output ratio would gradually increase from 1.30 in 2010 to 2.00 in 2020 and 2.25 in 2030. With an increase in this ratio, the

Figure 10.10: Solow Growth Decomposition under the Reform Scenario



Source: Authors' calculations.

marginal product of capital declines, and so does its contribution to GDP growth. On the other hand, the contribution of improvements in TFP would increasingly become most important, tying that of capital accumulation by 2025 and surpassing the 50% mark by 2030. Regarding the labor input, for most of the simulation period the contribution from the labor force would be negative given that the working-age population is expected to experience a declining trend in the next two decades. The contribution of human capital would be, conversely, positive and increasing in relative terms, reaching almost 10% by 2030. This is likely to be an underestimation of the role of human capital, however, because much of the gains in TFP could not be achieved were it not for strong human capital investment and growth.

4. Conclusions

Even during the protracted, 25-year-long civil war, Sri Lanka's economy was able to grow at an average rate of 4.6% per year, a rate higher than three-fourths of the countries around the world. Expectations for even higher growth in the aftermath of civil conflict are, thus, understandable. This chapter attempts to measure what can be projected for GDP growth in Sri Lanka in the next two decades under different scenarios for productivity improvement and public saving.

To be sure, Sri Lanka's high growth rate in the last three decades did not come for free. It took an increasing effort of resource mobilization in the country. In the mid-1970s, the rate of saving and investment were, respectively, 15% and 17% of GDP. By 2010, they reached 25% and 28%, respectively, an increase of at least 10 percentage points. The rise in national saving was fundamentally fueled and sustained by the private sector. Is it reasonable to expect increasing private saving rates in the future? Most likely, they will not rise much further. The demographic transition experienced in Sri Lanka indicates that in the next two decades the old dependency rate will rise considerably, producing a decline in private saving rates. This decline would be lessened if per capita income increased, as expected, but the trend would not be reversed.

Notwithstanding its high rates of capital investment in the last decades, Sri Lanka is still a country with a relatively low capital-to-output ratio and with significant infrastructure needs. The public sector, which currently features negative saving rates, has much room for reducing its deficits and increasing public investment. Similarly, external investors are likely to encounter attractive and profitable investment projects in the coming years in a reformed and peaceful environment. The government of Sri Lanka has the goals of increasing public saving to 1.5% of GDP by 2013 and allowing an increase in international investment in the country, amounting to a current account deficit of 4–5% in the coming years.

If these goals are achieved, what can be expected for GDP growth in the country? To answer this question, we have presented a neoclassical growth model with endogenous private saving, calibrated it to fit the Sri Lankan economy, and simulated the behavior of GDP growth rates and related variables under different scenarios. If improvements in productivity continue at the average rate experienced in the last decades (TFP growth of 1%), GDP growth would be above 6.0% in the first years and then decrease gradually to about 4.5% by 2015 and a bit over 2.0% by 2030. This is an adequate result but is much lower than what the Sri Lankan people and their government deem as necessary to develop. To increase growth, forceful economic and institutional reforms are needed. Under what we call the reform scenario, TFP growth would increase to an average rate of 1.75% per year, leading to GDP growth of about 6.5% in the next five years, 4.6% by 2020, and 3.5% by 2030, the end of the simulation period (see table 10.1). This robust growth performance would be supported at the beginning mostly by capital accumulation but later on mainly by productivity improvements.

The challenge, then, is how to obtain large and sustained productivity improvements, in the context of solvent fiscal accounts and international investment participation. We leave it for further work to identify the specific policy measures that can generate these essential improvements.

Table 10.1: Reform Scenario TFP growth of 1.75% per year (public savings raised to 1.5% of GDP by 2013)

	Year			
	2012	2015	2020	2030
GDP per capita growth	6.3%	5.3%	4.2%	3.3%
GDP growth	7.1%	6.0%	4.6%	3.5%
Solow decomposition - Contribution (%):				
TFP	28%	33%	42%	53%
Physical Capital	70%	64%	55%	41%
Human Capital	4%	4%	6%	7%
Labor Force	–2%	–2%	–3%	–1%

Source: Authors' calculations.

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