Policy Research Working Paper 10900

Long-Term Growth Prospects in Peru

Leveraging the Global Green Transition and the Reforms Needed to Become a High-Income Country

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Abstract

This paper uses the World Bank Long-Term Growth Model and extensions to study Peru's long-term growth prospects and its potential to attain high-income economy status. Under a business-as-usual baseline, Peru's potential GDP growth declines slowly from 2.1 to 1.7 percent over the next two decades, due mostly to demographic factors. In this baseline, it takes more than half a century to reach high income status. To accelerate growth, the paper considers moderate and ambitious reform scenarios for the non-resource sector through faster total factor productivity (TFP) growth, human capital growth, and higher investment rates. The ambitious reform path accelerates growth to an average of 4.3 percent in the simulation period (2024–50), allowing Peru to reach high-income status by 2045. The paper also considers a Global Green Transition scenario, where Peru takes advantage of higher global demand for copper from clean technologies. In that scenario, higher copper prices, greater exploration, improved mining technology, and reinvested copper windfalls increase baseline growth to 3.1 percent by 2035. If Peru were able to harness the global green transition and implement ambitious reforms in the non-resource sector, growth could accelerate to an average of 5 percent, and the country could reach high-income status by 2042.

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Long-Term Growth Prospects in Peru: Leveraging the Global Green Transition and the Reforms Needed to Become a High-Income Country[1]

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Keywords: Economic growth, human capital, investment, total factor productivity, innovation, education, market efficiency, infrastructure, institutions, Peru, green transition

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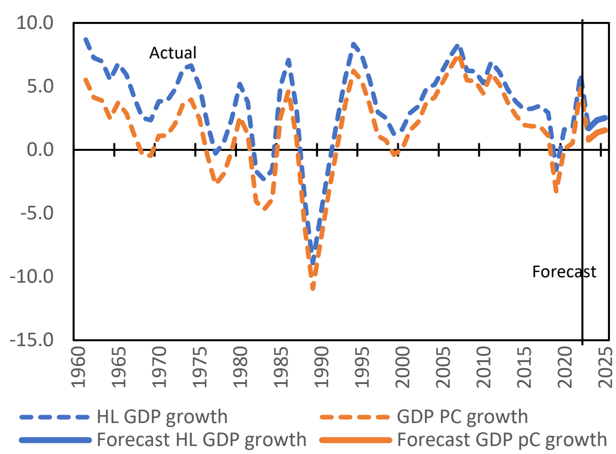
1. Introduction

Peru experienced strong and sustained economic growth in the post-1990 period, which supported remarkable gains in social and economic development. Between 2002 and 2019, Peru grew at an annual 5.1 percent rate on average (Figure 1), well above the 2.7 percent average in Latin America. High growth rates enabled Peru to double its per capita income and reach upper-middle-income status in 2008. Between 2002 and 2013, GDP growth was exceptionally high, averaging 6.1 percent annually (5.2 percent in per capita terms), driven by good economic reforms and the commodity boom.

However, economic growth halved to 3 percent in the 2014-2019 period, partly driven by the end of the commodity supercycle and because of a lack of substantial reforms. The less favorable external environment during the 2014-2019 period brought to light the more profound structural challenges of Peru's growth model, such as low productivity growth (World Bank, 2022). The pursuit of economic development in Peru in the coming decades requires the search for new growth drivers.

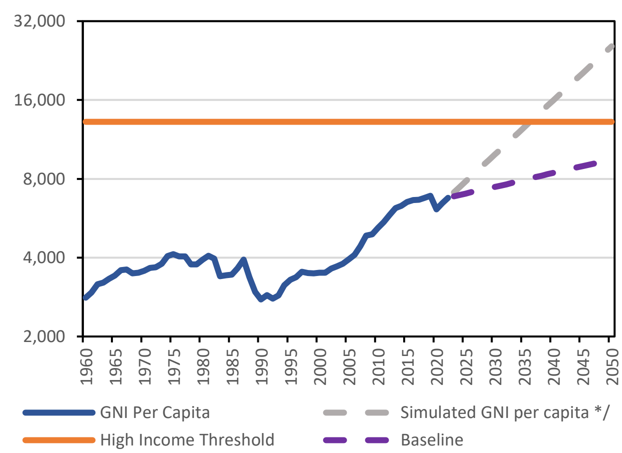
This paper studies Peru's long-run economic growth prospects and what it would take for the country to attain high-income (HI) status. Accelerating economic growth is crucial. For example, if Peru continued at its current trend growth rates in the post-COVID period of 2.5%, it would take almost half a century to achieve HI status. In contrast, if Peru grew at a rate of 5 percent, the average rate during the 2002-2019 period (including the commodity boom and bust period), it would only take 14 years (Figure 2).

Figure 1. Historical GDP Growth



Source: World Development Indicators and WB staff`s forecasts
Note: The series are the 3-year centered moving average.

Figure 2. Real GNI Per Capita[2]



Source: World Development Indicators.
*/ Simulated with a constant growth rate of 5% (2022-19 average).

We use the World Bank Long-Term Growth Model suite (LTGM, Loayza and Pennings 2022) to evaluate ways to boost growth and achieve high-income status more quickly. The standard LTGM is a Solow-Swan

[2] Methodology used for Figure 2: Calibrate the levels to the GNI per capita Atlas method (NY.GNP.PCAP.CD) for 2018, and then cast backwards using real GNI growth (NY.GNP.PCAP.KD.ZG). The horizontal line shown is the 2022-23 high income threshold.

style neoclassical growth model, though can be extended in a range of directions depending on the country and context. We use the LTGM Natural Resource Extension (LTGM-NR, Loayza et al. 2022) as our core model, as Peru is a resource-rich country. The LTGM-NR augments the standard neoclassical growth model with a natural resource sector and government fiscal policy that determines how resource revenues are spent. This modeling approach provides a more accurate analysis than the main LTGM for resource-rich economies, as it accounts for heterogeneity across the resource and non-resource sectors (Appendix A1). We also use the LTGM-TFP extension (Kim and Loayza 2019) and the LTGM-Human capital extension to model Total Factor Productivity (TFP) growth and human capital growth, respectively.[3]

We first model Peru's business-as-usual growth path, where the growth drivers – the investment-to-GDP ratios, TFP, human capital, and labor force participation rates – follow their historical or recent trends.[4] We find that potential GDP growth in Peru is likely to fall from around 2.1 percent in 2024 to around 1.4 percent in 2050, driven mostly by demographic factors, but with a secondary contribution from declining human capital growth (as the workforce is already better educated). As growth slows it takes even longer to reach HI status in the baseline—almost 65 years.

Next, we assess the extent to which domestic reforms to improve the investment rate, human capital and TFP growth can accelerate GDP growth. Specifically, we simulate moderate and ambitious shocks to the factors of production with targets based on the distribution of those growth fundamentals among HI countries. Ambitious reforms generate growth that averages 4.3 percent in the 2024-2050 period, compared to the 1.9 percent average in the business-as-usual baseline.[5] We also simulate the long-term growth under a global "green transition" scenario where the increased demand for copper, if the world achieves Net Zero Emissions (NZE), results in higher copper prices, higher copper investment, and greater exploration. The estimated GDP growth is roughly one percentage point higher compared to the baseline, which would help Peru considerably in achieving its growth targets. The combined scenario of the global green transition and ambitious domestic reforms accelerates Peru's GDP growth significantly and the country reaches the target of HI status by 2042.

The rest of the paper is organized as follows. Section 2 presents past growth dynamics. Section 3 discusses the assumptions used in the baseline simulation, presents the baseline growth path to 2050 and the contribution of each growth driver to the slowing growth rate. Section 4 presents the combined impact on GDP growth due to reforms on each growth determinant. It shows Peru's standing in comparison to structural and regional peers on five separate TFP determinants and quantifies the impact from converging to frontier countries on TFP growth. Section 5 presents the global green transition scenario, which analyses the effects of higher copper prices that would result from global NZE, a shock to the copper sector TFP, higher investment, and long-term production. It then combines the domestic reform and the global green transition scenario to quantify the combined impact of GDP growth. The conclusion provides a summary of the main findings and policy implications.

[3] The LTGM-HC tracks the years of schooling and the quality of education and health across age cohorts to determine the human capital of the workforce. In the LTGM-TFP, the TFP growth rate is calculated as the compositive effect of TFP determinants: innovation, education, market efficiency, infrastructure, and institutions. See the Appendix for details.
[4] Future demographic projections are taken from the United Nations (UN).
[5] Ambitious reform is the mix of shocks to the investment rate, human capital and TFP which are detailed in section 4.

2. Historical evolution of GDP growth and its drivers in Peru

During the 1990s, Peru experienced an average growth rate of 3.2%, closely tied to the implementation of economic reforms following the hyperinflation period of the 1980s. These reforms, primarily macroeconomic in nature, aimed at trade liberalization, privatization of non-profitable state-owned enterprises, fiscal discipline, financial sector reform, and the promotion of private investment. The combination of these measures resulted in a significant accumulation of capital and laid the foundation for growth in the new millennium.

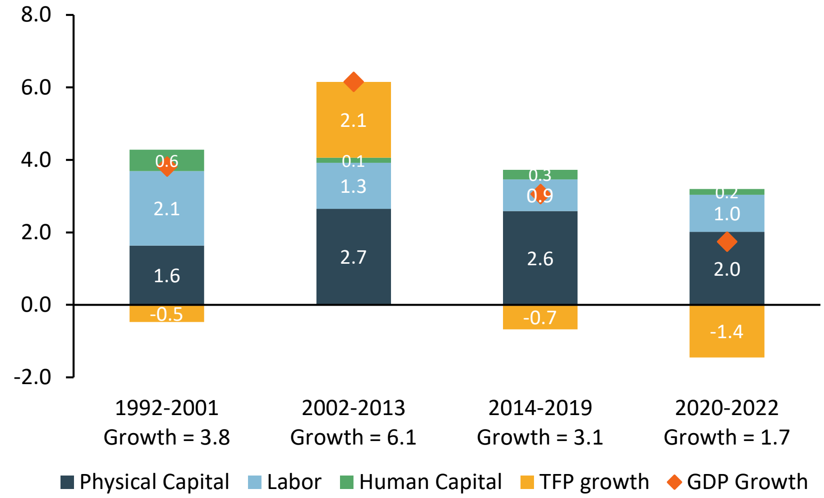
Building on this momentum, from 2002 to 2013, Peru's growth rate doubled compared to the previous decade, with an average rate of 6.1%. This success was driven by good macroeconomic policies, political stability, and favorable external conditions. The country emerged as one of the world's leading copper producers, thanks also to various large-scale mining projects that were launched during this time. The commodities boom contributed to a remarkable 73% growth in terms of trade, bolstering private investment, which tripled by the end of 2013. The accumulation of physical capital played a significant role, contributing 2.7 percentage points to the period’s overall growth, marking the highest value in the past two decades (Figure 3).

Furthermore, increased fiscal resources resulting from improved tax collection facilitated the financing of public investment. Total investment as a percentage of GDP reached 24%, the highest since the early 1980s (Figure 4). Additionally, there was 2.1% growth in TFP (Figure 5) of which Castillo and Rojas (2014) attribute a quarter to improved terms of trade. The fiscal revenue boost also supported reforms in health care and education, while new social programs provided strengthened assistance to vulnerable groups.

From 2014 to 2019, Peru faced unfavorable external conditions and a lack of new economic reforms, leading to a significant drop in its growth rate, almost cutting it in half to 3%. Although the macroeconomic fundamentals were stable, the lack of visible policy initiatives aimed at fostering sustained growth became apparent.

Both capital and productivity contributions were lower during this period (Figure 3). World Bank (2022) attributes the slow productivity growth to a predominance of small-scale enterprises and the absence of incentives to promote their expansion. High informality in Peru contributes to the overall lower productivity. The limited progress made in addressing these challenges can be linked to the weak capacity of public institutions. Institutional instability has eroded the state's ability to implement necessary reforms, develop quality infrastructure throughout the country, and mitigate market rigidities.

Figure 3. Factor contributions to Short Run GDP Growth, period averages, percentage points
(Excluding indirect effects of non-capital factors on capital deepening)



Source: MTI Growth Accounting Tool, WB Staff calculations

Amid the challenges, there were also some notable achievements. The 2002-2019 period saw positive developments in poverty reduction, a decline in inequality, and improvements in human capital (Figure 6). Peru has also made significant progress in improving access to education and quality of education in the last 20 years. The percentage of young adults (ages 25-34) with a secondary education increased from 43% in 2000 to 60% in 2017, and the percentage of young adults with a tertiary education increased from 12% to 20% over the same period. Human Capital's contribution to growth increased during 2014-2019 but deteriorated during the COVID-19 pandemic (see Figure 3).

Total population growth was close to 1.2% in the last decade after experiencing a downward trend since 1990 (Figure 7). Population growth has increased in the last 5 years due to Venezuelan immigration to Peru going from around 1.1% in 2014 to 1.9% by 2019. After the COVID crisis, the population growth decreased to 1% in 2022.

Between 2020 and 2021, during the COVID-19 crisis, accumulated GDP growth was less than 1 percent and the country is now recovering from this significant shock. Over this period the structural challenges were highlighted, and the potential growth was affected due the lower productivity and labor contributions.

Figure 4. Historical Investment-to-GDP (%)

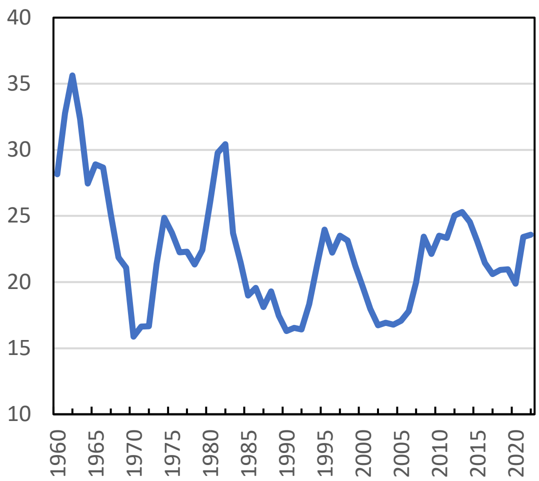


Figure 5. Historical TFP Growth (3yma)

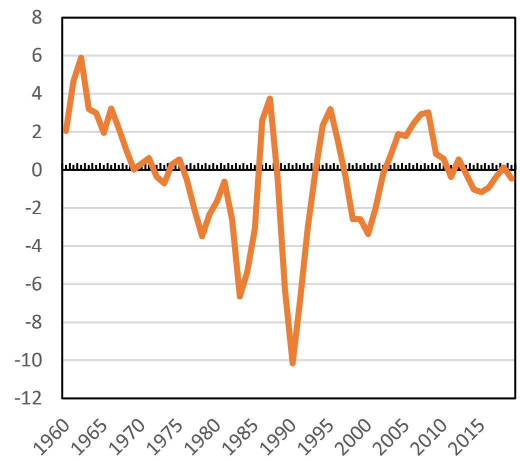


Figure 6. Historical Human Capital Growth (%)

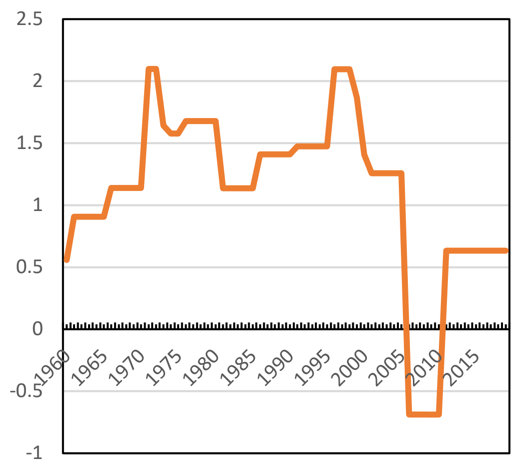
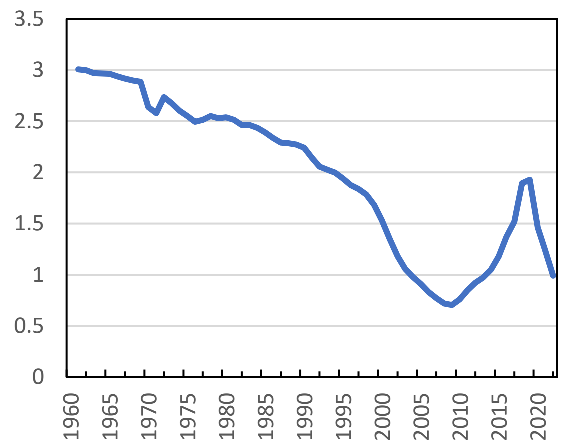


Figure 7. Historical Total Population Growth (%)

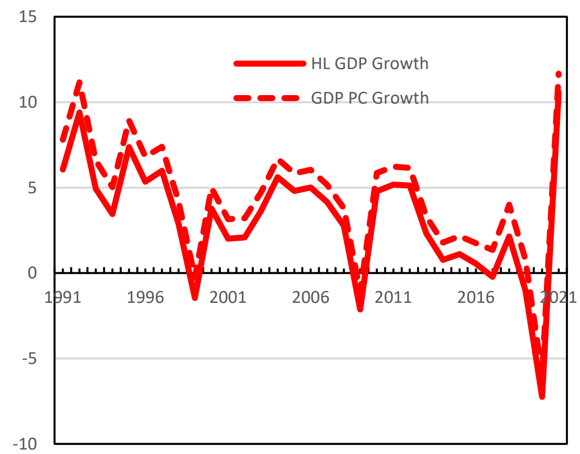


Source: World Development Indicators, Penn World Table 10.01

Box 1. Chile's Economic Growth Experience in Comparison to Peru

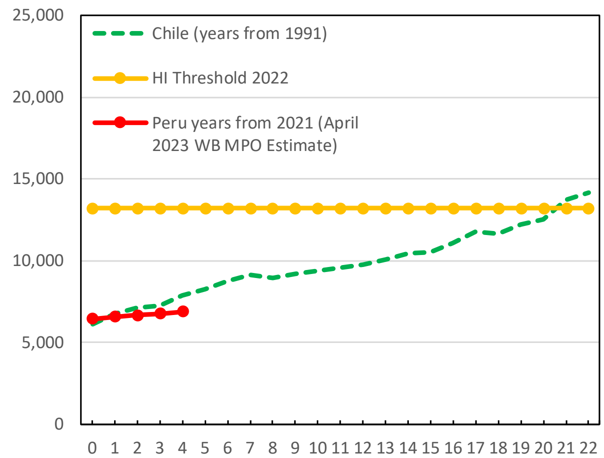
This box aims to compare the Chilean economic growth experience from 1991 (when Chile was at approximately at the same level of development as Peru in 2021) onwards. As Chile transitioned to high-income status, the historical drivers of growth were diverse, but were led by higher private investment, followed by higher TFP growth rates, and higher Human Capital growth rates, a demographic dividend that lasted for 22 years. Headline GDP growth and GDP per capita growth averaged 5.1% and 3.9%, respectively, throughout that process. Box Figure B1b shows that it took Chile 21 years to become a high-income economy.

Figure B1-a. Chile's Economic Growth Performance



Source: World Development Index

Figure B1-b. Chile's path to High Income Status



Source: WDI, WB projections.

Growth drivers during this time were 1) investment-to-GDP ratio averaged 23% (private investment averaged 20.5% and public investment 2.5%), 2) average saving was 22.3% and Current Account Balance-to GDP ratio was, on average, -0.8%, 3) human capital growth averaged 0.6%, 4) TFP growth averaged 0.5%, 5) the growth of the working age-to-total population ratio (WATP) was around 0.35%, indicating a demographic dividend throughout this period and 6) total population growth declined from 1.65% to 1.05%.

3. Growth drivers in the business-as-usual baseline

In this section we calibrate the LTGM-NR model to simulate Peru's business-as-usual baseline over the 2023-50 period. To create a baseline for the Peruvian economy in the long run, we calibrate the future paths of the growth drivers such as investment, human capital, the growth of TFP in the non-resource and natural resource sectors,[6] as well as other key parameters. These assumptions are summarized in Table 1. We calibrate the LTGM-NR as the foundation of the analysis and add the LTGM-TFP extension and the LTGM-HC extension to simulate non-resource sector TFP growth and human capital growth, respectively. We use population growth projections (by age cohort) from the UN for demographic trends until 2050.

[6] The resource sector is composed of the copper mining sector, which is around 8 percent of the total GDP and is expected to grow in the short run by around 2 percent due to the entrance of the Quellaveco mine. In the long run, the depletion in reserves will shrink the sector to 6 percent of GDP and grow below 1 percent on average.

The remaining projections are determined by assuming that long-term trends in Peru remain constant and by performing steady state calculations.

The labor share in the non-resource sector $\beta_{NR} = 0.49$ is calibrated by adjusting the aggregate labor share proportionally in relation to non-resource GDP (see Loayza et al. 2022).[7] Using the calibration of Loayza et al. (2022), the capital share in the mining sector $(1 - \gamma_i)$=0.84 is calculated with the natural resource rents shares (γ_i) from the Global Trade Analysis Project (GTAP), and averaged over 2004, 2007, 2011, and 2014. The tax rate in the resource sector, $\tau^R = 0.62$, is calibrated using data on government natural resource revenues and resource GDP from the IMF's World Commodity Exporters Dataset (IMF-WCE). For Peru, the $\tau^R = 0.62$ is set to match the historical average in the last 20 years of resource revenues as a share of resource GDP. Following the standard model of the LTGM-NR, we calibrate the fiscal rule like a Balanced Budget-Hartwick Rule, which implies a marginal propensity to invest of $\theta = 1$.

GDP for 2021 is taken from World Bank's World Development Indicators (WB-WDI), in constant 2015 U.S. dollars. In the absence of comprehensive information on GDP at the copper sector level, we proxy GDP in the copper sector by the exports of copper. For Peru, GDP in the copper industry is set to match the value of exports as a share of GDP in 2021. The export data is taken from the UN-Comtrade Database (UN-CT), which provides information on export value for all 11 commodities and all 56 countries, with a time series that usually starts in 2002.

As in the standard LTGM, the initial stock of capital-to-GDP ratio of 3.6 is calculated using the most recent observation from PWT 10.01. The initial capital stock is split across activities to equalize the initial marginal revenue product of capital across the copper and non-resource sectors.[8] In the resource sector, the reserves are calibrated using the initial stock of reserves in industry i is taken 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 model requires the paths of exogenous variables from 2021 until 2050, and we assume that the variables will follow recent trends in the long-term. Discoveries of natural resources are calibrated using data on annual production and reserves of the resource good i, taken from the USGS. 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. In the baseline, the trajectory of discoveries of good i from 2021 to 2050 is set to match the historical average over the past 15 years of 6.5 million metric tons (mt).

The trajectory of copper prices is from Chile's Advisory Committee projections for the Copper Reference Price 2023, which is a survey of 20 experts that publishes their expected prices of copper until 2032. We use the average of the 20 responses and convert it to real prices of 2015 in US$/mt. For the trajectory of prices between 2032 and 2050 we assume copper prices are constant at their 2032 value.

[7] $\beta_t^{NR} = \beta_t^{PWT} \times GDP_t / GDP_t^0$ where β_t^{PWT} is the share of labor compensation in GDP in period t, taken from Penn World Table 10.01 (PWT10), and GDP_t^0 is non-resource GDP in period t.

[8] Following Loayza et al. (2022), the initial capital stock in activity j must satisfy the following $N + 1$ equations,

$$K_{2021}^j / Y_{2021}^{ij} = \frac{(1 - \gamma_i) GDI_{2021}^j}{(1 - \beta^{NR}) GDP_{2021}^0 + \sum_{i=1}^N (1 - \gamma_i) GDI_{2021}^i} \, for \; i = 0, \dots, N$$

where $GDI_{2021}^j \equiv \left(\frac{\bar{p}_t^j}{\bar{p}_{2015}^j} \right) GDP_{2021}^i$ denotes real GDI in activity i, year t; $\gamma_0 = \beta^{NR}$.

In the default model, we decompose total investment into private and public investment (these have identical effects in the LTGM-NR, but have different determinants). Private investment as a percentage of GDP is assumed to remain at approximately 17.7%, which is the historical average between 2004 and 2019 according to data from the Central Bank of Peru. Public investment is set at 4.7% using data from the IMF-FAD, which represents the average of the last 10 years of available data.

Total factor productivity growth of the non-resource sector is generated using the LTGM-TFP extension (Kim and Loayza 2019) assuming that the determinants of TFP - innovation, education, market efficiency, infrastructure, and institutions – increase at their historical rate over the past decade.[9] This results in an almost-constant path of TFP growth over the simulation period of 0.5%-0.6%, which is similar to the historical average over 2004-19.

The human capital growth path for the baseline is generated using the LTGM-HC extension, assuming that the current quality and quantity schooling and health of today's children persists throughout the simulation period. This generates human capital growth of 0.3% in 2022 and declines to about 0.1% in 2050. We assume the average expected years of schooling in the future is the same as that of today's children, 12.7 years, taken from the World Bank Human Capital Index. Because today's new workers are better educated than older workers moving to retirement, the average human capital of the workforce grows over time – despite no increase in the schooling of children. The rate of human capital growth slows over time due to rising average education quantity of the workforce, which reduces the educational gap between new workers and incumbents. 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 years old that are not stunted (see equation below).[10] In the baseline, we assume that schooling quality remains at its original level of 0.65, ASRs stay at 0.88 and the not stunted rate stays at 0.87. Data on the health and education variables are taken from the World Bank's Human Capital Project. 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.

[9] Specifically, we applied the average annual change in the overall determinant index over 2010-2019 to the period of 2021-2050.

[10] $h_t^{HCI} = Schooling_t \times Health_t = e^{\phi(YrsSchool_t \times Quality_t - 14)} \times e^{\frac{[\gamma_{Stunt}(NotStunted_t - 1) + \gamma_{ASR}(ASR_t - 1)]}{2}}$. The return to education is assumed to be 12%.

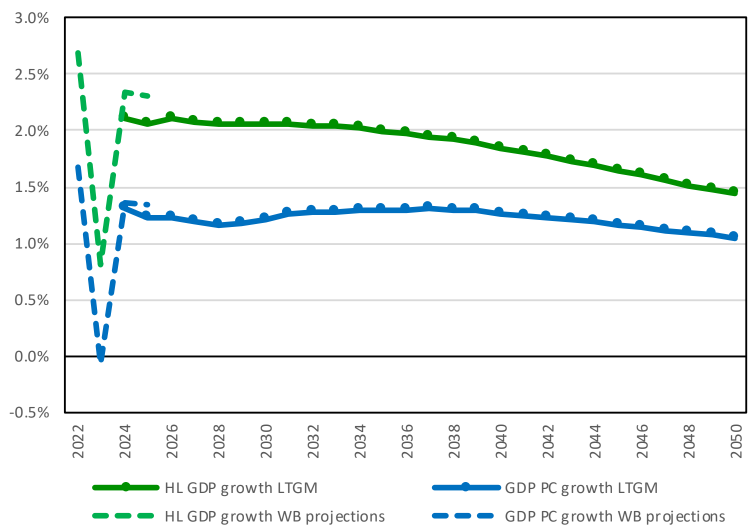
Table 1. Assumptions for the Peru Business-as-Usual Baseline (2023-50)

	Value	Unit of measurement	Time Series	Source/Target
Baseline				
A. Main Parameters				
Depreciation rate (δ)	4.2%	Percent/year	2009-19 average	PWT 10.01, Average depreciation rate of the capital stock
Labor share in the non-res sector (β_{NR})	0.49	[0, 1]	2019	PWT 10.01, Share of labor compensation in GDP at current prices
Capital share in mining sector (1-γ)	0.84	[0, 1]	2004-14 average	GTAP, 2004, 2011, 2007, 2014
Govt. share in the resource sector (τR)	0.62	Share of copper GDP	Last 20 years, average	WEO, IMF-WEC, UN-Comtrade
Marginal propensity to invest (θ)	1.0	Share of extra res. Revenue	Hartwick Rule (invest windfalls)	WEO/Match historical public investment to expenditure ratio
Long-run public investment	4.7%	% of GDP	Last 10 years, average	WEO, general government investment
B. Initial Values				
Per capita GDP	6,446.9	Real, 2015 US$	2021	WDI, Real GDP per capita (NY.GDP.MKTP.KD)
Exports of copper	8.2%	% of initial PC GDP	2021	UN-Comtrade
Capital-to-GDP ratio	3.6	[0, inf]	2021	PWT 10.01
Non-resource sector	3.15	[0, inf]	Equalize the VPMK across sectors in 2019	
Copper sector	0.46	[0, inf]	Equalize the VPMK across sectors in 2019	
Reserves of natural resources				
Copper sector	81	Million of Metrics tons	2017	U.S. Geological Survey
C. Assumed paths of standard drivers of growth, 2021-50				
Total Investment	22.4%	% of GDP	2004-2019 average	WEO total investment - WEO public investment
Private, Investment	17.7%	% of GDP	2004-2019 average	WEO total investment - WEO public investment
Public, Investment	4.7%	% of GDP	2004-2019 average	WEO total investment - WEO public investment
TFP, non-resource sector	0.6%	Annual growth rate	LTGM-TFP	Aggregate TFP growth from PWT 10.01
TFP, mining sector	-0.5%	Annual growth rate	TFP average growth in Chile in 2000-17	Productivity Commission Chile (2016)
Human Capital	0.2%	Annual growth rate	LTGM-HC	PWT 10.01, Human Capital index (hc)
Demographics:				
Population	0.7%	Annual growth rate	2021-2050, average	ILO's estimates, total population
Working-age population	65.2%	% total population	2021-2050, average	ILO's estimates, population aged 15-64
Population, Male	49.2%	% total population	2021-2050, average	ILO's estimates, population, male
Participation rate, Male	88.1%	initial % of working age pop.	2021	WDI, Labor force participation rate, male (SL.TLF.ACTI.MA.ZS)
Participation rate, Male	0.4%	Annual growth rate	2021-2050, average	WDI, Labor force participation rate, male (SL.TLF.ACTI.MA.ZS)
Participation rate, Female	74.1%	initial % of working age pop.	2021	WDI, Labor force participation rate, female (SL.TLF.ACTI.FE.ZS)
Participation rate, Female	1.0%	Annual growth rate	2021-2050, average	WDI, Labor force participation rate, female (SL.TLF.ACTI.FE.ZS)

3.1. BAU baseline over 2023-2050.

Under a baseline or business-as-usual growth path, Peru's potential GDP growth would slow down from 2.1 percent in 2024 to around 1.4 percent by 2050 (Figure 8). The BAU baseline measures the potential growth rate of the economy and is not a forecast of actual growth. The recent forecast of GDP growth and GDP per capita growth (dotted lines in Figure 8) are slightly above the potential growth as it incorporates the short run expectations about investment and trade balance effects due to starting operations of Quellaveco mine, one of the top ten copper mines in terms of proven reserves. However, short run deviations will not have much effect on the long-run growth potential that is the focus of this paper. This section explains the drivers of current growth, and the reasons for the declining trend. Under this baseline simulation, Peru will achieve HI status in 64 years.

Figure 8. Peru's BAU Baseline GDP and GDP PC Growth

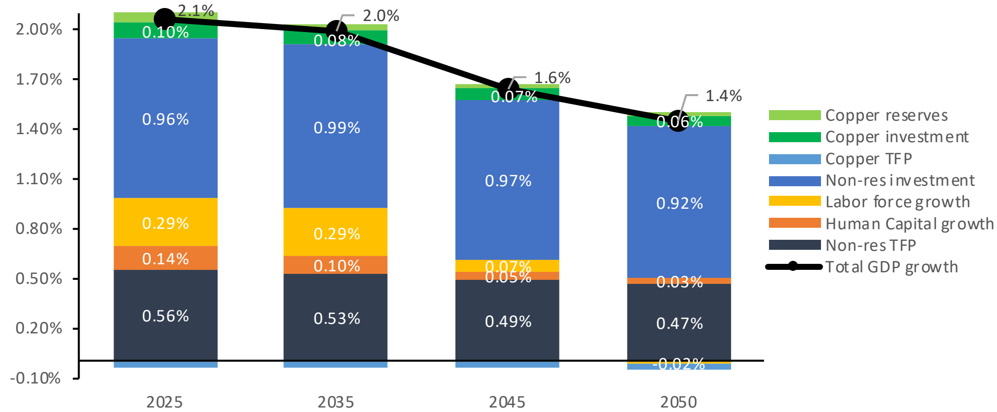


Source: LTGM simulations, World Bank Staff's calculations

What explains current trend growth rates?

Investment in the non-resource sector and non-resource TFP growth are the largest drivers of current economic growth, followed by a declining contribution of labor. Current growth can be decomposed using log-linear approximation of the production function. Investment in the non-resource sector is the most important growth driver in different periods of the simulation, with a contribution around 0.9ppts, which is almost half of total growth (Figure 9). The next largest contribution is from TFP growth of non-resource sector, with a contribution of 0.5ppts, with labor force growth of 0.3ppts.

Figure 9. Contributions of Factors to GDP Growth (short-run method)



Source: LTGM simulation, World Bank staff.

Why is the baseline growth rate declining?

To understand why baseline growth falls, we run counterfactual simulations where the growth rate of each growth driver is kept constant at current rates. Table 2 depicts the impact of each driver on the fall in GDP growth between 2023-2050 (figures are in Appendix A2). These are normalized contributions, which means that the individual contributions are scaled so that they add up to the total fall in growth. The normalization is necessary because over the long term, the model is non-linear.

Demographics are the most important factor and explain almost two-thirds of the 0.78 ppts fall in GDP growth over 2023-50. Population growth is expected to fall 0.3 ppts over 2023-2050. 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.[11] The falling working age-to-total population ratio (WATP ratio) reduces GDP and per capita GDP growth in the late 2030s. The growth rate of the WATP falls by 0.3 ppts by the end of the simulation period, resulting in a normalized contribution of 29% to the overall fall in GDP growth over 2023-50.

The combined fall in TFP growth in the resource and non-resource sectors and HC growth over 2023-50 account for around 0.3 ppts of the fall in the GDP growth over 2023-50. The baseline TFP growth rate in the non-resource sector is expected to decrease from 0.61 percent (the value in the counterfactual) to 0.53 percent over the next three decades (Figure A2-e, appendix), a 0.1 ppts decline. The TFP growth rate in the resource sector is assumed to be constant at -0.5 percent in the baseline scenario (in the counterfactual, resource TFP growth is kept constant). Human capital growth falls from 0.31 percent (the value in the counterfactual) to 0.09 percent in the baseline, a 0.2 ppts decline (Figure A2-f, appendix). While this decline in human capital growth is larger than that of TFP non-resource growth, GDP growth rates are also less sensitive to human capital, resulting in a similar contribution.

[11] The declining population growth increases GDP per capita growth (in contrast, other growth drivers have the same effect on GDPPC and GDP growth). In the baseline, GDPPC growth decreases by 0.29 ppts, and declines 0.46ppts with constant population growth.

The decrease in the growth rates of reserves reduce GDP and per capita GDP growth along the period 2023-2050. The growth rate of the reserves per capita falls by 2.5 ppts by the end of the simulation period, resulting in a normalized contribution of 0.04 ppts to the overall fall in GDP growth over 2023-50. This result suggests that GDP growth rates are less sensitive to reserves per capita.

Table 2. Understanding the Drivers of Peru's GDP Growth Slowdown[12]

	Total Decrease of GDP Growth (2023-2050)	
	Headline GDP Growth	
Baseline	-0.78 ppts	100.0%
	Factor Contribution	**Normalized Share of Fall in Growth**
Population Growth	-0.27 ppts	30.2%
Working age-to-total population Growth	-0.26 ppts	29.4%
HC Growth	-0.15 ppts	17.0%
Non-Res. TFP Growth	-0.12 ppts	14.1%
Copper TFP Growth	-0.04 ppts	4.8%
Copper Reserves growth	-0.04 ppts	4.5%

Note: Investment is held constant throughout the simulation period, so we remove its contribution. The capital-to-output ratio is also approximately constant.

Decelerating economic growth is not a unique phenomenon to Peru. Kose and Ohnsorge (2024) finds that an internationally widespread decline in potential growth occurred in 2011-21 relative to 2000-10. This widespread decline reflected a multitude of factors. In terms of the production function framework, all the fundamental drivers of growth faded in 2011-21: TFP growth slowed, investment growth weakened, and labor force growth declined. The study also finds that recessions after strong shocks such as the Covid-19 pandemic, were associated, on average, with a decline of about 1.4 percentage points in potential growth even after five years.

4. Reform scenarios for Peru to achieve High-Income status.

In this section, we examine how different factors, namely investment, human capital, and TFP, affect economic growth in the non-natural resource sector. Our objective is to assess the feasibility of accelerating GDP growth to achieve HI status within the next two decades through domestic reforms. We analyze the individual impact of each growth factor and find that growing at around a 5 percent rate is not possible with a single shock to only one of them. Therefore, we simulate moderate and ambitious reform scenarios combining different shocks to all the aforementioned factors together. These scenarios allow us to examine the potential outcomes and determine the best approach for achieving the desired economic growth and HI designation. We first consider reform scenarios to TFP, as they are some of the most important (Section 4.1) and then reforms to boost human and physical capital (Section 4.2), with the resulting growth paths discussed in Section 4.3.

[12] Because the model is nonlinear, the sum of the effects of changing growth factors at one-by-one is not equal to the total change in growth when the growth factors change together. This is especially true over the long term when capital in the non-resource and resource sectors change.

Box 2. The Long Term Growth Model - TFP Extension

This box describes the LTGM-TFP extension (Kim and Loayza 2019) used to quantify the specific determinants to TFP growth. The determinants of TFP are classified into five categories: innovation, education, market efficiency, physical infrastructure, and institutions (governance). For each category, a set of subcomponent indexes are constructed based on the most relevant and available empirical indicators using the factor analysis. These subcomponent indexes are combined into an overall TFP index using the principal component analysis (Table B2-a). To measure the relative contribution of the five main determinants of TFP growth, the variation of the TFP growth rate is decomposed to that explained by each determinant across countries over the period 1985–2014. Finally, the relationship between the overall determinant index and the change in the growth rate of TFP is estimated as follows:

$$TFP\ growth_{c,t} = \beta_0 + \beta_1 \ln\left(Index_{c,t-5}\right) + \beta_3 \ln(rtfpna)_{c,t-5} + \theta_c + \delta_t + \varepsilon_{c,t}$$

$TFP\ growth_{c,t}$: annualized TFP growth over $t-5$ and t.
$Index_{c,t-5}$: overall determinant index at $t-5$.
$rtfpna$: $TFP\ level\ (2011\ =\ 1)$
θ_c: country effect.
δ_t: time effect.

Table B2-a. TFP determinants and Related Indicators	
Innovation	R&D expenditure, public and private (percent of GDP) Number of patents, residents, and nonresidents (per 100 people) Number of scientific journal articles (per 100 people)
Education	Government expenditure on education (percent of GDP) Proxy for primary education: secondary enrollment rate (gross percentage) Proxy for secondary education: PISA score Proxy for tertiary education: completed tertiary education (percent of population 25+)
Market Efficiency	Goods market: Doing Business index. Financial market: IMF Financial development index Labor market: Minimum wage (percent of VA per worker), severance pay for redundancy dismissal (weeks of salary), and share of women in wage employment in non-agricultural sectors
Infrastructure	Fixed telephone and mobile subscription (per capita) Length of paved roads (kilometer per capita) Electricity production (kilowatt per capita) Access to improved water source (percent of population) Access to improved sanitation facilities (percent of population)
Governance	Voice and accountability, corruption control, government effectiveness, political stability, regulatory quality, and rule of law

Source: Kim and Loayza (2019).

4.1. Reforms to boost TFP growth in Peru

Identifying ways to boost TFP growth is often challenging because TFP growth is a residual. While reforms to schooling and the investment climate (such as access to credit) are better understood, TFP is generally regarded as a residual component of growth representing economic efficiency and technological improvement. However, this loose and broad definition impedes a precise understanding of how to improve TFP growth.

In this section, we investigate ways to achieve the moderate and ambitious reform TFP paths using the LTGM-TFP extension of Kim and Loayza (2019). Based on an extensive literature review, Kim and Loayza (2019) identify the main determinants of economic productivity as innovation, education, market efficiency, infrastructure, and institutions (Box 2). Based on underlying proxies, that paper constructs indexes representing each of these main categories of productivity determinants and, combining them through principal component analysis, obtains an overall determinant index. TFP growth has a positive and significant relationship with the proposed TFP determinant index, and 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 Innovation and Infrastructure determinants of TFP perform worse in Peru than in its peers. Within the five components of TFP growth in Kim and Loayza (2019), Peru underperforms in Innovation and Infrastructure compared to aspirational and structural peers, lagging also behind the LAC, UMIC and HIC Median (Table 3). These are the two areas where the country possesses a wider gap with the rest. The stance regarding Market Efficiency and Institutions is lower than the aspirational peers, although it surpasses some of the structural peers and the regional median. Peru fares relatively well compared to peers on Education.

Table 3. Main determinants of TFP in Peru and peer countries

		Aspirational Peers			Structural Peers					
	Peru	Chile	Malaysia	Romania	Ecuador	Colombia	South Africa	LAC Median	UMIC Median	HIC Median
Overall determinant index*	43.8	56.4	60.8	55.2	38.8	44.6	50.4	40.4	44.9	78.9
Innovation	3.6	11.7	23.7	13.0	7.9	6.5	11.2	4.0	6.6	40.2
Education	53.2	62.5	55.5	66.4	52.1	48.8	51.2	41.9	51.1	71.5
Market Efficiency	67.0	71.3	82.3	71.7	48.1	68.3	79.3	55.5	63.2	86.9
Infrastructure	42.4	52.8	60.4	53.7	43.4	46.6	46.7	45.4	48.3	68.9
Institutions	56.8	76.1	67.0	63.7	50.0	55.2	60.0	53.4	53.6	82.0

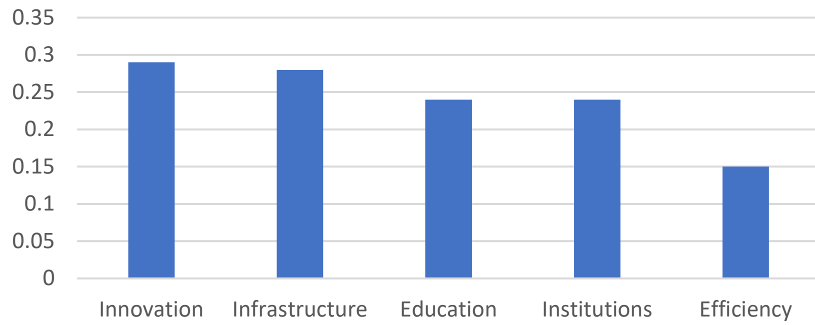
*The composite index of the subcomponent indexes for the five categories of the determinants

Scale from 1 to 100 (best) as of 2019 except for group medians

Convergence to HI country values in the Innovation and Infrastructure sub-dimensions produces the largest boosts to growth, followed by Education and Institutions, and lastly market efficiency. To assess the sensitivity of TFP growth to each component, we simulate a shock to the five components one at a time, mimicking the trajectory of the 75th percentile index among HIC for each component (while the rest are held constant). We then compare the results to a scenario where all components remain constant. Among the five determinants, raising the Innovation and Infrastructure components to this target will lead to the fastest TFP growth, 0.29 and 0.28 percentage points higher on average annually between 2024-2050 (Figure 10). Education and Institutions have the second largest impact, at about 0.24 percentage points. Market Efficiency has a slightly lower impact on TFP growth.

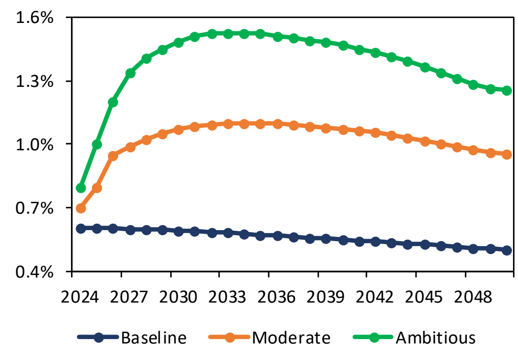
Experiences from other countries, such as the fast-growing Asian Tigers and China, show that sustaining high TFP growth for a long period is possible but requires continuous reforms to remove constraints and distortions in the market. Given that Peru's TFP fundamentals could be further improved, closing the gap with HI countries will be important to sustain high TFP growth. However, it will require substantial efforts to remove market imperfections to improve market competition, infrastructure, and human capital as well as to create an enabling environment for innovation.

Figure 10. TFP growth difference (percentage points)



Note. The comparison is between a scenario of convergence to the 75th percentile index among HIC in each component and a baseline with constant levels

Figure 11. TFP growth path



Source: LTGM simulations, World Bank Staff's calculations

The moderate and ambitious reform scenarios assume the TFP determinant index converges to HI country levels, but with higher targets within that group for the ambitious scenario. In the moderate reform scenario, each subcomponent index for innovation, education, market efficiency, infrastructure, and institutions, increases linearly to the 75th percentile among HI countries by 2050, which results in TFP growth accelerating from 0.6% to 1.1% by 2035, and then maintaining that pace for the next decade (Figure 11).[13] The ambitious scenario is simulated similarly, but we assume that each subcomponent reaches the highest overall index among HI countries by 2050. While this target is extremely optimistic, it is mostly the rate of improvement that drives TFP growth, and many countries have had periods of rapid reform. The ambitious reform scenario results in TFP growth accelerating to 1.6% by 2035, though with some deceleration in the following decade. However, even with 1.6% TFP growth in the ambitious scenario, Peru is unable to reach HI status, with growth only reaching 3%. Instead, complementary reforms are needed to physical and human capital accumulation, which we discuss next.

[13] Although the resulting path for TFP growth is moderate, the pace of reform would have to be fast.

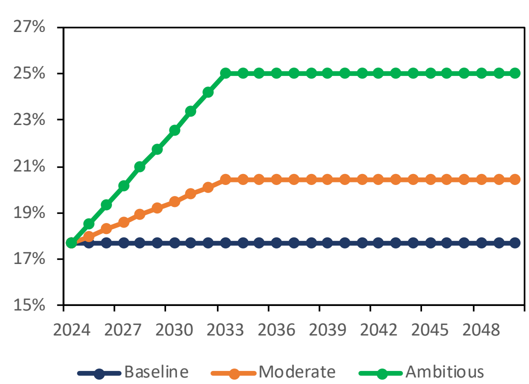
4.2. Physical and human capital

The reform scenarios assume increases in private investment above the 17.7% of GDP in the baseline, based on reforms such as an improved business environment and greater access to credit. In the moderate reform scenario, we assume that private investment will increase to the 75th percentile of private investment among high income countries (20.4% of GDP over 2015-19) in the span of 10 years. While private and public investment are perfectly substitutable in the LTGM-NR, the investment rate is formed by combining an increase in private investment with an unchanged 4.7% of GDP rate for public investment (so total investment is 25.1% of GDP). The ambitious reform scenario is similarly calibrated but targets a private investment rate at the 90th percentage of HI countries, which results in private investment increasing to 25% of GDP by 2033 (Figure 12) (so total investment at 29.7% of GDP).

Increases in investment bring a large boost to growth. Figures 16 and 17 show that improvements in investment are projected to spur GDP growth by 0.5 and 1.1 percentage points on average in the moderate and ambitious reform scenario respectively in the entire period to 2050.

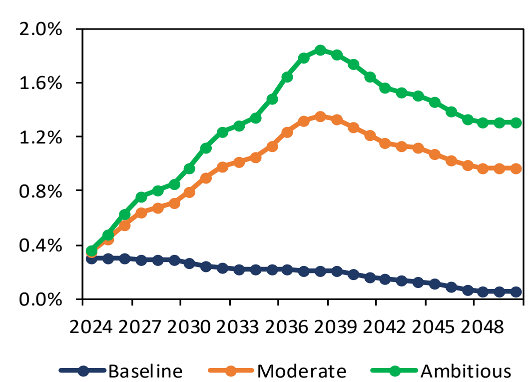
For human capital, we raise levels to match those seen in the 75th percentile of high-income countries (HIC). In the moderate scenario, we set targets based on median values from available data for HIC countries, resulting in Expected Years of Schooling at 13.6, Quality at 0.83, Adult Survival Rate at 0.94, and Fraction of Children Under 5 Not Stunted at 0.94.[14] In the ambitious scenario, we aim for even higher targets, aligning with the best values observed in HIC countries. Both moderate and ambitious reforms can enhance the Human Capital Index, but with a delay as illustrated in Figure 13. This delay arises because these reforms influence today's children, who take time to enter the workforce.

Figure 12. Private Investment to GDP ratio path



Source: LTGM simulations using LTGM-HC extension

Figure 13: Human Capital growth path



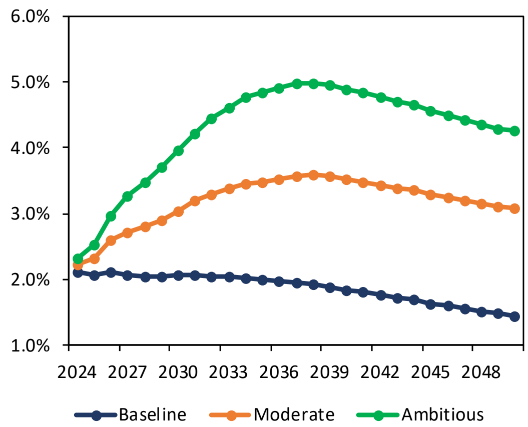
Source: LTGM simulations using LTGM-HC extension

[14] We assume the reforms are implemented immediately through the education and health systems. However, the reforms take some time to have their full effect in Figure 13 because it takes time for healthier and better-educated children to become more productive workers. Older children who have completed part of their education already are only partially treated.

4.3. Combined results from reform scenarios

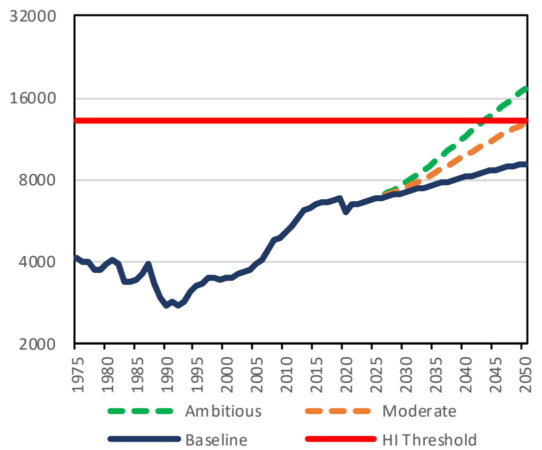
The effects of the reform scenarios on the GDP growth outlook are shown in Figure 14 and on the GNI per capita (relative to high income) in Figure 15. In the moderate reform scenario, headline GDP will accelerate to achieve GDP growth of 3-3.5 percent from 2030 onwards, with a growth boost of 1.6ppts by 2050. Instead, with an ambitious reform package, GDP growth accelerates to 4.6% by 2033, which is 2.6 ppts above the baseline, and HI status is achieved by 2045.[15]

Figure 14: GDP growth path



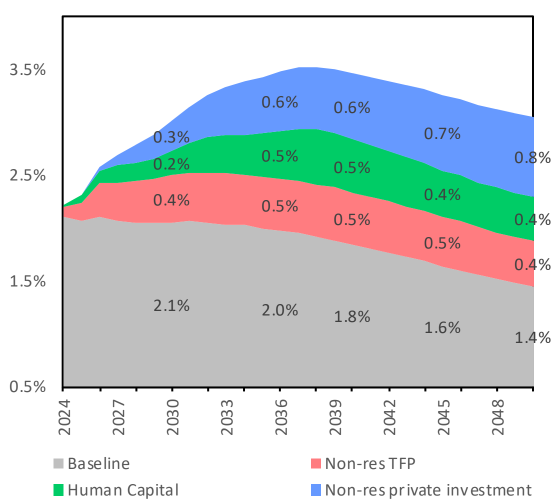
Source: LTGM simulations

Figure 15: Evolution of GDP per capita with the simulated scenarios*



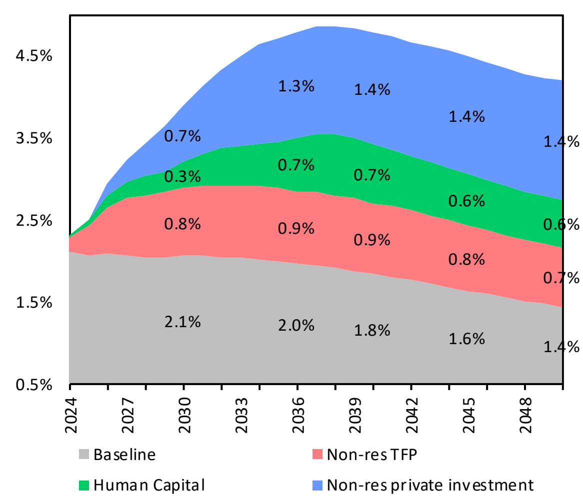
Source: LTGM simulations. *The series are in logarithms base 2

Figure 16. Moderate reform contributions to GDP growth



Source: Peru's LTGM simulations, World Bank Staff

Figure 17. Ambitious reform contributions to GDP growth



Source: Peru's LTGM simulations, World Bank Staff

[15] Policies can also aim to raise the employment share of the working-age population, in particular of discouraged workers or groups with historically low participation rates, such as women. The female employment-to-population ratio was 16ppt below that of men in 2018, and closing this gap will increase long run GDP by around 12% (Pennings 2022). However, those policies are not discussed in this paper.

5. The global energy transition as a long-term growth factor

The global energy transition implies a considerable increase in the demand for copper in the following decades, which represents a golden opportunity for the Peruvian economy. The increased mineral intensity from greener technologies, such as renewable energy and electric vehicles, in addition to the new infrastructure needed, will significantly raise the demand for minerals during the next two decades (World Bank, 2020). Recent projections forecast the world's appetite for copper will be more than double the current global mine production (S&P Global, 2022). Achieving global climate ambitions will thus require a substantial increase in copper supply. Being the second largest copper producer in the world—representing around 10 percent of the global supply—and having the second largest mine capacity (IHS Markit, 2022), Peru's production would need to double if it were to maintain its share of the global copper market. While this is a highly ambitious scenario, it illustrates that copper could be an important driver for Peru's long-term growth. The mining sector currently contributes around 10 percent of GDP and 15 percent of total tax revenue. Optimizing the use of fiscal resources from mining is thus also important to potentiate a future copper windfall.

To leverage the energy transition, Peru needs to create the right conditions to attract the necessary investments, guarantee that mineral exploitation is environmentally sustainable, and promote profits that reduce territorial and social disparities. The efficient extraction and processing of copper will require large-scale capital investment and improved technological methods to ensure sustainability. This requires a "Climate-Smart Mining" approach to mineral exploration, extraction, and refining in Peru, which includes a clear strategy for maintaining the country's position as a major global player in the supply of critical minerals while decarbonizing the mining value chain; improving processing technologies; reducing mining's footprint on water, energy, and waste. It also requires ensuring human rights and enabling territorial development in mining regions, to create an appropriate political environment for future mining projects.

As above, we use the LTGM-NR to analyze global energy transition growth scenarios in Peru, though now we shock growth drivers in the resource sector. The resource sector dynamics differ from the non-resource sector in three ways. First, production depends on the industry-specific productivity, the stock of physical capital, and the country's proven reserves of the required natural resource (but not on labor or human capital). Second, the stock of natural resources increases with an exogenous stream of discoveries but depletes via extraction. Third, all production generated in the resource sector is exported at international commodity prices, which fluctuate exogenously and have a direct impact on the income generated by the sector. The LTGM-NR includes a fiscal rule that determines whether extra government revenue from the taxes on copper production are saved abroad, spent on government consumption, or spent on public investment (which has the same effects on growth as private investment). The first two have little effect on growth, though the final "Hartwick" rule can generate substantial extra investment and growth when commodity prices are high.

5.1. Supplying the Global Green Transition Scenario

We construct a Global Green Transition Scenario using the path for future copper prices estimated by Boer et al. (2021). The paper identifies metal-specific demand shocks, estimates supply elasticities, and determines the price impact of a global net zero emissions scenario on metal prices. According to these estimates, in a net-zero emissions scenario, copper prices would increase by more than 60 percent compared to the baseline, peak around 2030,[16] and stay at these high levels for more than a decade. This scenario uses global copper consumption provided by IEA (2021). The impact of such a scenario on Peru's GDP growth depends on the country's fiscal policy because it determines public investment, which is a main channel through which an initial shock to commodity prices generates long-term effects on growth. The increase in copper prices raises government revenues, leading to an upsurge in government expenditure. As such, the model-implied long-term trajectory of GDP growth is different depending on whether the increase in revenue is only spent on government public investment (Hartwick's rule), if windfalls are completely saved (Structural Surplus Rule), or if a share of windfalls are invested, and the rest consumed (Balanced Budget Rule)[17] (building on the baseline).

To achieve Net Zero Emissions (NZE) by 2050 will likely require major innovations in technology and policies that encourage long-term investments to increase supply. In this scenario, we simulate a doubling of long-term copper production in Peru by 2035, which is similar to the copper production estimates for Peru under a Net Zero Emissions scenario provided by S&P Global (2022). In the model this could be achieved with a combined shock: first, higher copper prices drive a higher investment rate as the larger demand generates a plan to increase investment; based on the historical evidence, we use a long-term elasticity of total private investment as a share of GDP to the percentage change in the copper price of 0.25. This scenario entails an increase in production driven by higher investments in the mining sector which would be unlocked from a clearer pro-development policy agenda, rule of law, and an improved political environment.

Second, there is a boost to TFP in the copper sector in the short run as the industry does not operate at full capacity and the global green transition boosts the utilization rate of other inputs; in particular, we assume that through innovation, adoption of new technology and more efficient equipment, the copper sector TFP annual growth rate increases to 1 percent in 2025 and then gradually returns to baseline by 2050.[18]

The global energy transition can increase long-term growth in Peru and move the country closer to HI status. The results show that GDP growth accelerates significantly under this Supplying the Global Green Transition scenario (figure 18 below, the orange line is roughly one percentage point higher on average than the baseline in the period 2024-2050). Thus, this would help Peru considerably in achieving its growth target; the energy transition gives more opportunities and fiscal resources to Peru to do the domestic reforms needed to increase productivity, investment and human capital and accelerate economic growth.

5.2. Combination of the Supplying the Global Green Transition scenario and domestic reforms

In this section, we combine the Supplying the Global Green Transition scenario from Section 5.1 and the domestic reforms to increase Human Capital and TFP growth shown in Section 4. The scenario which includes ambitious reforms yields a 5 percent GDP growth on average in the simulation period (Figure 18). Under this scenario, Peru would reach the HI threshold in 2042 (Figure 19).

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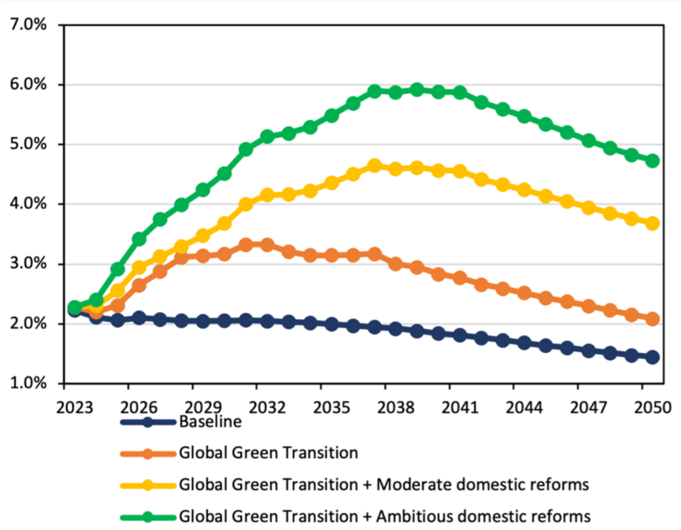
[16] Rises in demand are front-loaded and the initial price boom induces a supply reaction.

[17] This scenario sets the share of investment in total expenditure to 25 percent, which was the observed average in 2000-2019.

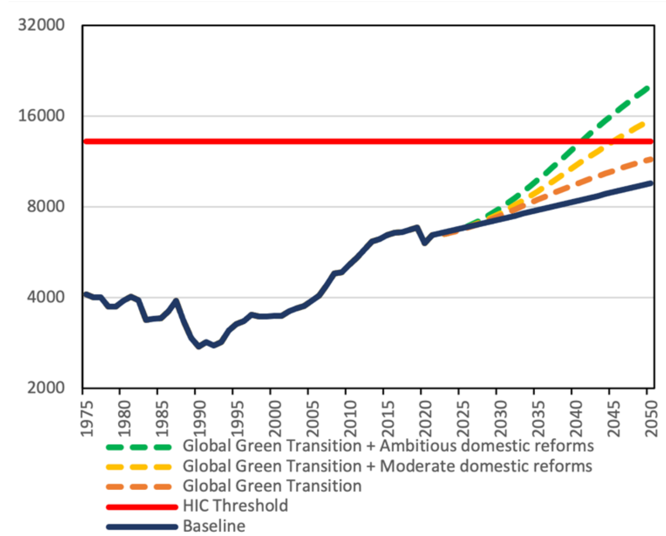
[18] The baseline for TFP growth of -0.5 percent in the copper sector is based on the evidence from Chile, where the long-run copper TFP has stagnated or even declined over the past decades ("Productivity in the Chilean Copper Mining Industry", National Productivity Commission, 2017).

Figure 18. Real GDP growth



Source: Peru's LTGM simulations, World Bank Staff

Figure 19. Real GNI Per Capita Level simulations with Global Green Transition scenario



Source: LTGM simulations, World Bank Staff.

6. Conclusions

Using the LTGM-NR, we simulate that Peru's potential GDP growth is likely to slow down from 2.1 percent in 2024 to around 1.4 percent by 2050 under a BAU baseline, with the slowdown mostly due to demographic factors. At this pace, the objective of becoming an HI country would be reached in 64 years.

In this paper, we also study moderate and ambitious reform scenarios that boost investment, TFP and human capital growth to accelerate growth. Section 4.1 delves deeper into TFP growth drivers, given it is one of the most important components of the reform scenarios. Higher TFP growth can be driven by improving its five determinants: innovation, education, market efficiency, infrastructure and institutions. Peru underperforms compared to its structural and aspirational peers especially in the innovation and infrastructure components, and boosting these to the level reached by frontier countries can accelerate TFP growth. Sustaining these levels for a long period however requires substantial and continuous reforms. We model moderate and ambitious reform scenarios for TFP by benchmarking Peru against HICs and show that under the ambitious reform scenario the TFP growth rate could increase by up to 1 percentage point compared to the baseline over the simulation period. This needs to be implemented in combination with higher investment rates and human capital to lead Peru closer to HI status. While an ambitious domestic reform scenario is not by itself sufficient to yield a 5% GDP growth rate, such as that experienced during the 2000s, it is able to generate a long-lasting boost to the GDP growth rate to 4.3% and the country reaches HI status by 2045.

This paper also evaluates how the global energy transition can be an opportunity to accelerate growth in Peru, by quantifying the effects of higher commodity prices, discoveries of natural resources, higher investments, and an improvement in the copper-sector TFP. We find that in a highly ambitious Net Zero Emissions scenario, copper production in Peru can double by 2035. This increases real GDP growth by around one percentage point compared to the baseline. This would require major innovations in technology and policies that encourage long-term investments to increase supply. In particular, the efficient extraction and processing of copper will require large-scale capital investment and improved technological methods to ensure sustainability. Hartwick rules that invest all extra public resource revenues from the commodity windfall generate the largest increase in GDP. Higher investments in the mining sector would be unlocked from a clearer pro-development policy agenda and an improved political environment.

Adding ambitious domestic reforms to increase Human Capital and TFP to the “Supplying the global green transition” Scenario yields 5 percent GDP growth on average in the forecast period. Under this scenario, Peru would reach the HIC threshold in 2042. The global energy transition gives more opportunities and fiscal resources to Peru to implement the domestic reforms needed to increase productivity, investment and human capital and accelerate economic growth.

Increasing long-term growth to a level that would put Peru on a path to reach HI status requires strong reform efforts. The country can benefit from a green growth dividend, but to fully leverage it, it will need to advance important structural reforms. The mining sector needs to create the necessary conditions, within a context of social legitimacy, to move forward with the development of an extensive mining project pipeline and increase the sector’s productivity. Promoting exploration, making the projects in the pipeline viable, and ensuring the normal operation of current activities require strengthening environmental sustainability and improving the socioeconomic impact of mining projects. Peru faces the challenge of improving the sector’s policies and management to guarantee its long-term contribution to the country’s sustainable development (World Bank 2021). In addition, given that mining is a capital-intensive sector, reforms in the non-resource sector are also important for inclusive growth. Reforms that improve human capital, increase investment and the productivity of the non-resource sector are also needed. Achieving this would require efforts from diverse stakeholders, as sustainable collaboration among the government, the private sector, and civil society will be necessary.

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7. Appendix

A1. LTGM-NR model description

The LTGM-NR model disaggregates the economy into a non-resource sector (Sector 0) and resource sector (Sector R). This appendix develops the main equations used in the paper (more details are in Loayza et al. (2022)).

The non-resource sector. The structure of the non-resource sector is identical as the standard LTGM (see Loayza and Pennings (2022)). The representative production function is defined by:

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

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 participation rate (labor force to working-age-population ratio).

The natural resource sector. The setup of the natural resource sector is built on a Cobb-Douglas function of proven reserves (R) and physical capital (K), with decreasing returns in both R and K (equation (2)). This function has the desired property that the first reserves are relatively easy to extract, 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 loans.

As countries produce multiple commodities, the natural resource sector, R, is further disaggregated into N non-renewbable 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.

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

Where A_t^i is the TFP in industry 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,

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

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

Equation (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.

Real GDP and real GDI. The two measures of the size of an open economy are: Real Gross Domestic (GDP) and Real Gross Domestic Income (RGDI). The non-resource good is freely trade with a constant price of $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.

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)):

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

RGDI is a measure of purchasing power. For GDI, exports are deflated by the import price index. In this model, imported goods are of the non-resource (numeraire) good, and so have a constant price of 1. 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).

$$Y_t = Y_t^0 + Y_t^R = Y_t^0 + \sum_{i=1}^{N} \bar{p}_t^i Q_t^i \tag{7}$$

Investment. Investment is divided into private (i_t^p) and public (i_t^g) investment (see equation (8)). Also, total investment is allocated across sectors and industries of the economy (equation (9)),

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

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

In the LTGM-NR, private investment is an exogenous share of GDI, and public investment depends on the government's fiscal rule.

We also need to determine the allocation of aggregate investment across the non-resource and different industries. According to Loayza et al. (2022), to keep the model simple, to aggregate we use a rule of thumb where investment is allocated across the different activities proportionally to the marginal efficiency of capital and the sector's relative size (in terms of capital shares), as below:

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

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

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

where $MRPK_t^j$ denotes the marginal revenue product of capital (the dollar value of the marginal product of capital) in activity j, $1-\gamma_0 \equiv 1-\beta$, $Q_t^0 = Y_t^0$ and $MRPK_t^{DS}$ is a Dixit-Stiglitz (DS) aggregator of the $MRPK$ across all activities. The aggregator weights each activity by their capital shares, K_{t-1}^j / K_{t-1}.

The model we use is the default LTGM-NR, which is a simplified model of LTGM-NR-External-Balance, a complex model is developed in Loayza et al. (2022). The default model has two characteristics:

First, private investment is assumed to be an exogenous fraction of GDI. Second, public investment as a share of GDI responds of fluctuations in resource revenues according to the following rule:

$$i_t^g = \bar{\iota}_t^g + \theta(z_t^R - \breve{z}_t^R) + \varepsilon_t \tag{13}$$

where $z_t^R - \breve{z}_t^R$ are cyclical government resource revenues (as share of GDI) – i.e., the deviation of actual resource revenues z_t^R from their "structural" or long-run values $\breve{z}_t^R$. The parameter θ is the marginal propensity to invest resource revenues, and the term $\varepsilon_t \equiv \bar{\iota}_t^g (z_t^R - \bar{z}_t^R)/\tau_R$ is a technical adjustment to prevent double accounting, and τ_R is a flat tax rate.

Government resource revenues are defined by:

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

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

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

Fiscal Rule. The marginal propensity to invest 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.
- $\theta = \theta^{hist}$ captures a BBR (Balanced Budget Rule), where θ^{hist} is the historical fraction of the expenditure that is spent in public investment. In this case, when the cyclical resource revenue increases by ne dollar, all windfall is spent, but only the fraction θ^{hist} in extra spending is channeled to investment, the remaining is on government consumption.
- $\theta = 1$, all cyclical resource revenue is spent, but it falls only on public investment, as prescribed un BBR-HR (Balanced Budget-Hartwick Rule).

A2. Extra graphs explaining the declining GDP growth in the baseline

Figure A2-a. Constant Population Growth counterfactual

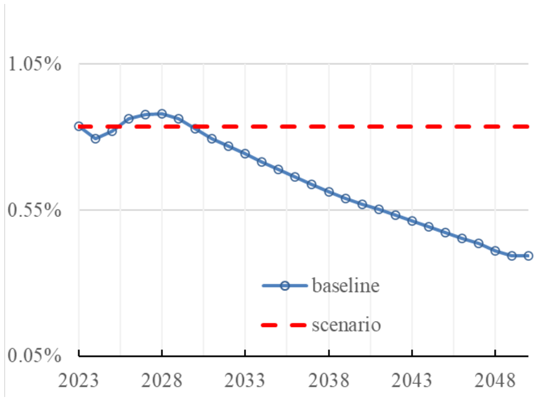


Figure A2-b. Effect of Population Growth on GDP Growth

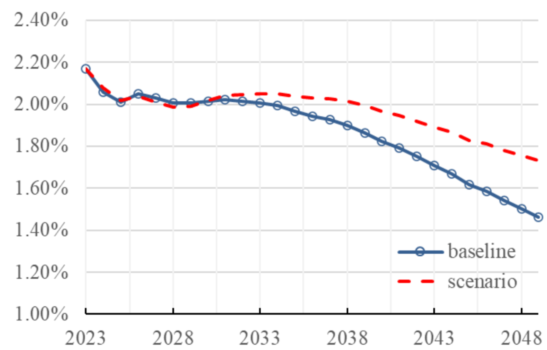


Figure A2-c. Constant Working age-to-total population Growth counterfactual

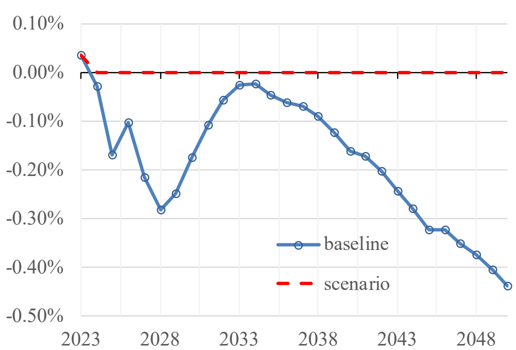


Figure A2-d. Effect of Working age-to-total population Growth on GDP Growth

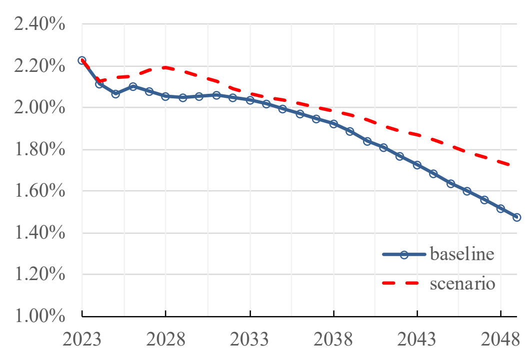


Figure A2-e. Constant Human Capital Growth counterfactual

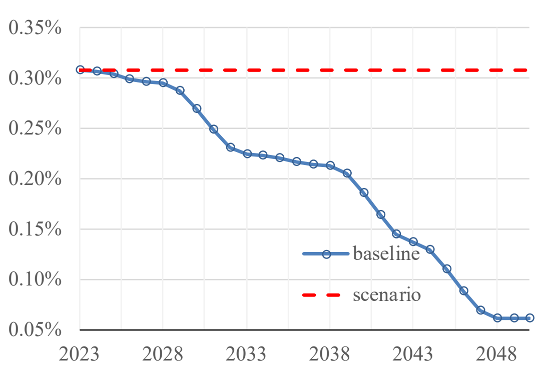


Figure A2-f. Effect of Human Capital Growth on GDP Growth

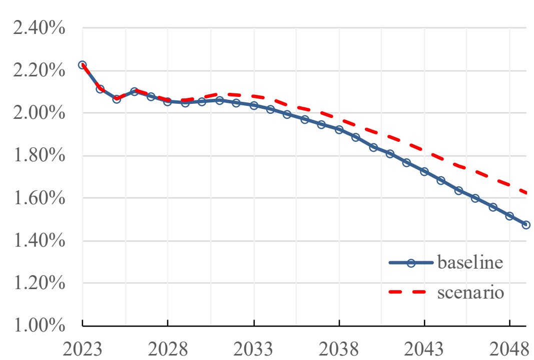


Figure A2-g. Constant TFP Growth counterfactual

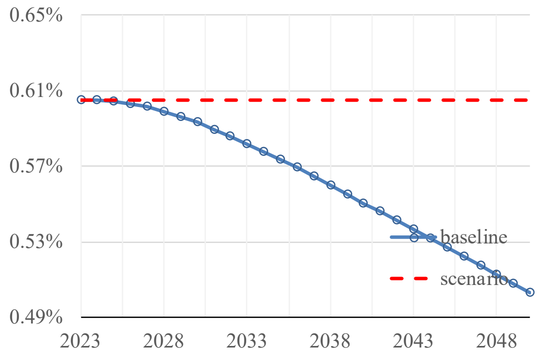


Figure A2-h. Effect of TFP Growth on GDP Growth

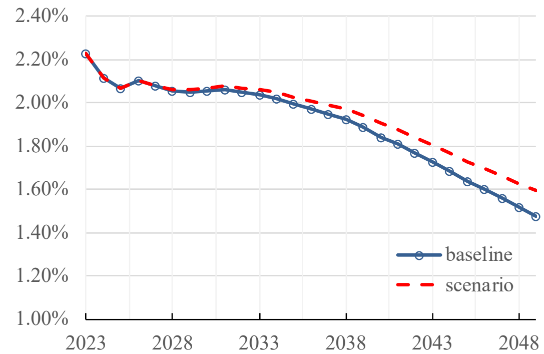


Figure A2-i. Constant Copper TFP Growth counterfactual

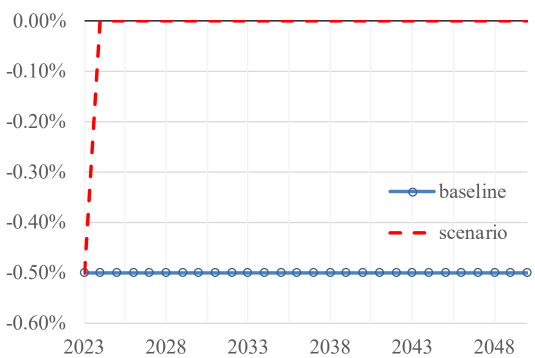


Figure A2-j. Effect of Copper TFP Growth on GDP Growth

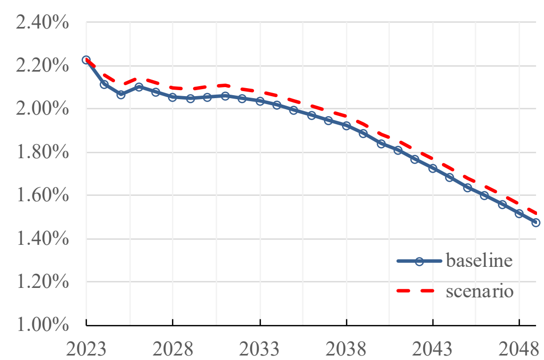


Figure A2-k. Constant Copper Reserves Growth counterfactual

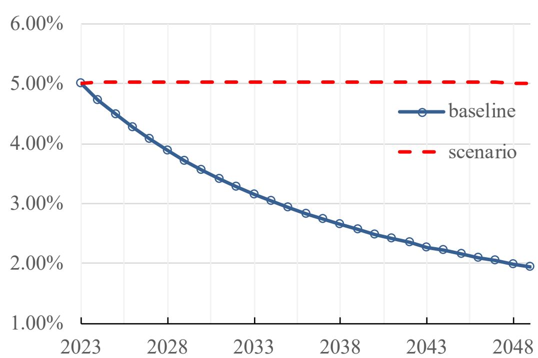
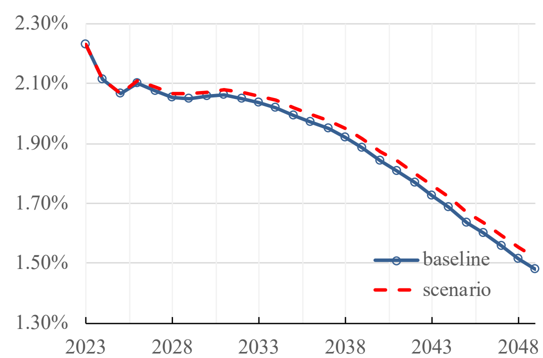


Figure A2-l. Effect of Copper Reserves Growth on GDP Growth



A3. LTGM-TFP extension additional simulations

Following Chile's path within LAC can boost TFP growth. We use the model to shock each sub-indicator to reach the level of the country with the highest Overall Index in the region, Chile, in ten years and see the impact on average TFP growth (Table A3). Closing the gap with Chile regarding the number of scientific and technical journals published and the PISA score would each yield 0.12 percentage points increase in TFP growth. Chile also scores high in Institutions, and mimicking its trajectory in the sub-indices of Control of corruption and Rule of law would also increase TFP growth in the margin.

Table A3. Shocks to each indicator of the TFP determinants to mimic Chile`s trajectory

TFP Determinants	Indicators	Change in TFP growth (in pp) if Peru reaches the level of the country with the highest overall Index in LAC (Chile) in 10 years
Innovation	R&D expenditure, public and private (% of GDP)	0.04
	Number of patents (/100 people)	0.04
	Number of scientific and technical journals published (/100 people)	0.12
Education	Government expenditure on education (% of GDP)	0.08
	Secondary completion rate (% of relevant population)	0.00
	Tertiary completion rate (% of population aged 25 and above)	0.00
	PISA score, average across math, science, and reading	0.12
Market efficiency	World Bank Doing Business scores	0.07
	IMF Financial Development Index	0.09
	Minimum wage (ratio to value added per worker)	0.02
	Severance pay for redundancy dismissal (weeks of salary)	NA
	Women in wage employment in the nonagricultural sector (% of total nonagricultural employment)	NA
Infrastructure	Fixed telephone (per 100 persons)	0.04
	Mobile subscription (per 100 persons)	0.01
	Electricity production (kw per 100 persons)	0.05
	Paved road (km per 100 persons)	0.01
	Access to improved sanitation facilities (% of population)	0.02
	Access to improved water source (% of population)	0.02
Institutions	Voice and accountability (freedom of expression, citizen's participation in politics, etc.)	0.05
	Control of corruption	0.10
	Government effectiveness (the quality of public services and policy implementation, etc.)	0.07
	Political stability (the absence of politically motivated violence)	0.01
	Regulatory quality (the ability of government to implement regulations promoting private sector development)	0.05
	Rule of law (the extent to which citizens have confidence in and abide by laws)	0.10