WPS8285

POLICY RESEARCH WORKING PAPER   8285

Public Infrastructure and Structural Transformation

Fidel Perez Sebastian
Jevgenijs Steinbuks

Abstract

This study argues that public infrastructure is an important though previously neglected driving mechanism of the structural transformation process. To assess its significance quantitatively, this study first develops a multisector neoclassical growth model with heterogeneous firms, where public infrastructure contributes to firms' production and mitigates the barriers to firms' entry. The model is calibrated using data from Brazil, a country that has significantly expanded its infrastructure in recent decades, yet remains in deep need of further infrastructure improvements. The accumulation of infrastructure accelerates the structural transformation through generating higher returns and lowering entry costs in sectors with greater public capital intensity. In the simulations, public capital formation explains about 15 percent of the process. The paper also shows the effects of different barriers to public capital formation on the structural transformation and GDP per capita.

Public Infrastructure and Structural Transformation[*]

Fidel Perez Sebastian[†] and Jevgenijs Steinbuks[‡]

[†]Department of Economics, University of Alicante and Hull University Business School.
[‡]Development Research Group, The World Bank.

1 Introduction

As Herrendorf et al. (2014), among many others, argue, the process of structural transformation, that is, the reallocation of inputs to more productive activities, is recognized as an important feature of successful economic development. Focusing particularly on the three largest sectors of the economy, we can further characterize this process as the reallocation of productive resources from agriculture to manufacturing and services, and later from agriculture and manufacturing to services.[1] Public infrastructure formation is another important process that has recently gained a prominent place in the economics literature. Infrastructure represents a key complementary factor to private production inputs and includes, for instance, streets, roads, highways, airports, mass transit, sewers, water systems, electricity and communication networks (e.g., see Aschauer, 1989).[2] Furthermore, our understanding of how these two important processes interact is limited. To fill the gap, this paper pursues two important goals. First, we want to assess the significance of public infrastructure formation in the structural transformation, and vice versa. Second, we want to understand how different constraints to public capital accumulation affect the stock of infrastructure in the economy, the structural transformation, and Gross Domestic Product (GDP).

A brief examination of the available cross-country data points signals a significant correlation between the two processes. Figure 1 shows two charts with cross-sectional data for 263 nations provided by the World Bank. The left panel of Figure 1 plots the average income share of agriculture against the average number of monthly power outages, over the period 2006-2015. We observe that economies that depend more heavily on agriculture experience, on average, a larger number of power outages. The right panel of Figure 1 displays the mean values of the income share of manufacturing against average monthly power outages for the

---

[1] We adopt the definition of these three sectors based on Herrendorf et al's. (2014) survey of the literature on structural transformation. In particular, the agriculture sector includes cultivation and breeding of animals, plants, and fungi. The services sector refers to the tertiary sector: financial, business, distribution and personnel services. Finally, the manufacturing sector captures all production activities that fall outside agriculture and services.

[2] We employ the terms public capital and public infrastructure as interchangeable.

Figure 1: Income shares of agriculture (left panel) and manufacturing (right panel) versus average power outages per month,
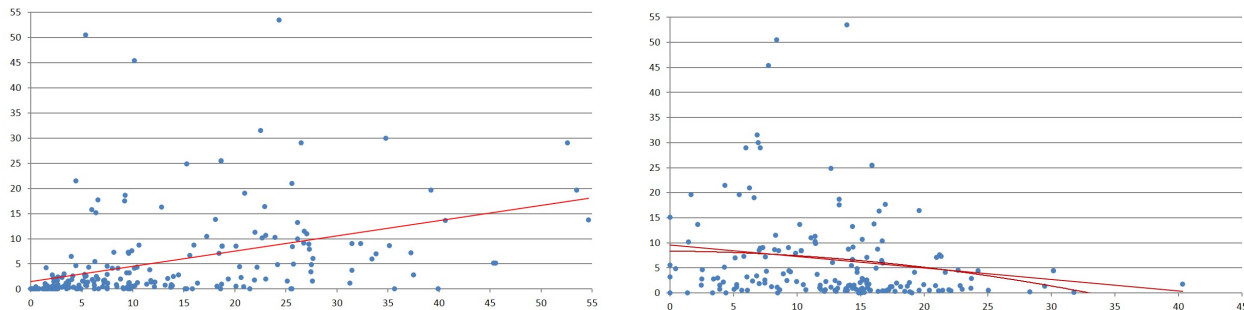
2006-15, 263 nations (source: World Bank, Enterprise Surveys
(http://www.enterprisesurveys.org/))

above time interval and same sample of countries. Here, we see that electricity infrastructure improves with the share of manufacturing in GDP, reducing the average number of outages. Interestingly, the hump-shaped relationship between GDP and the income share of manufacturing found in the cross-section of countries, documented for example by Herrendorf et al. (2014), does not appear in the right panel, where both fitted curves (linear and quadratic) are always strictly decreasing. This finding suggests that the correlation between the two is not merely a consequence of richer economies providing better infrastructure, and it, therefore, deserves further research.

To achieve our goals, we develop a multisectoral general equilibrium model of unbalanced economic growth and later analyze it quantitatively.[3] In this framework, the three sectors – agriculture, manufacturing, and services – coexist within a closed economy, except for the capital market that is open. They experience an exogenous sector-specific productivity growth. There are three main actors: firms, households and a government. We deviate from the existing literature by introducing public infrastructure and heterogeneous firms. Public infrastructure is a complementary factor that increases the productivity of private inputs. Firms have plant-specific productivity and are free to enter and exit markets. We consider

---

[3]The unbalanced growth feature of the model should not be perceived as a caveat. As Herrendorf et al. (2014) argue: "[in order to study the structural transformation process] focusing on frameworks that yield exact balanced growth is probably overly restrictive. The literature should instead focus on building models that can quantitatively account for the properties of structural transformation and in the process assess the importance of various economic mechanisms."

firm heterogeneity because, besides the standard complementarity between public and private capital shown in the earlier literature (e.g., see Aschauer, 1989, and Reinikka and Svensson, 2004), public infrastructure in our model also helps to reduce fixed costs of operation. That is, the lack of sufficient public capital acts as a barrier to the entry of firms into markets. The size of the fixed costs also contributes to endogenously determine the average productivity level in each industry and affect input reallocation across sectors.

This second effect of public infrastructure to which we refer above is motivated by the observation that some fixed operating costs such as payments, depreciation and maintenance for certain indivisible equipment like self-generating electricity machines, boreholes and water storage, personnel and freight transport, and radio communication equipment depend on the quality of public utility networks and roads (e.g., see Lee and Anas, 1992, Kessides, 1996, Foster and Steinbuks, 2008, and Steinbuks and Foster, 2010). In many developing countries the problem of deficient public infrastructure is further exacerbated by financing constraints that prevent smoothing these fixed costs (Steinbuks, 2012). On the other hand, good public infrastructure is conducive to the creation of large business clusters that generate increasing returns and lower barriers to firms' entry (Porter, 2000).

The quantitative analysis in our study is based on Brazilian data. Brazil is widely considered to be in deep need of infrastructure investment. The Global Competitiveness Report 2016-17, for example, ranks Brazil's quality of overall infrastructure at 116th place out of 138 nations. Unlike many developing countries Brazil also offers comparable data across sectors on gross value added, employment levels, and size and number of firms. We focus on the post-hyperinflation period, between 1995 and 2013. Over this period, the value added shares of agriculture and manufacturing have declined, and one of services increased. As expected, these patterns are replicated by the sectoral employment shares. As regards the firm size, the manufacturing sector has, on average, the largest firms, followed by the services sector, and the agriculture sector that has the smallest firms. The average establishment size remains

fairly stable across all sectors between 1995 and 2013.[4]

Our results show that the accumulation of infrastructure accelerates the process of the structural transformation. When sectors are complementary, their income share increases with the relative product price. Because services are the least intensive in public capital (see, e.g., Melo et al., 2013), the relative price of tertiary products grows faster as infrastructure accumulates, and hence the reallocation of resources towards that sector speeds up. This acceleration effect is reinforced by agriculture because it is the most intensive sector in public capital. At the same time, the increasing importance of services – the least intensive sector – reduces the incentives for public capital formation.

To the contrary, the effects that propagate through the fixed costs can go in the other direction. Because relative output prices in the model increase with the relative fixed costs that the sector faces and these expenses decline with public capital, additional infrastructure formation induces a smaller share of the sector with larger fixed costs. Taking the size of the average firm as the correlate of the fixed costs firms face, the manufacturing sector, which has the largest average firms' size, will also have higher fixed costs. As a result, public capital will help to reduce the relative price of manufacturing products and, as a consequence, the Gross Value added (GVA) share of this sector. The shares of the other two industries – agriculture and services – which, in the Brazilian data, have smaller firms than manufacturing, will conversely increase. Thus, public capital formation speeds up the reallocation of resources towards the services sector through its effect on the firms' fixed operating costs, and slows down the reallocation away from the agriculture sector.

Based on our model simulations, public capital formation explains 5 and 15 percent of the total variation in the GVA shares of manufacturing and services, respectively, observed in the Brazilian economy over the period 1995 to 2013. In the agriculture sector, public capital

---

[4]The evidence on the relationship between a country's income per capita level and average firm size is not conclusive. For example, using data on the manufacturing sector, Alfaro et al. (2009) find that firm size decreases with the level of income across nations, and Laincz and Peretto (2006) report no trend in average firm employment in the U.S. More recent papers, such as Poschke (2017) and Bento and Restuccia (2017), on the contrary, document that average establishment size is positively correlated with GDP per capita in the cross-section of countries.

formation generates a change in the GVA share that is larger than the one obtained from the data and accounts for 59% to the combined contribution of public infrastructure and relative TFP growth.

We also run some experiments that relate the model simulations to real-life policies. The first two consider the fall in the Brazilian GDP-share of public capital formation from 5.7 percent in the 1970s to 3.4 percent – the mean value for the interval 1985 to 2009 – and assess the consequences of having maintained it during the whole period at the 1970s average. First, we look at an increase in the ratio of the public capital formation to GDP as a consequence of a less partisan view of public spending that generates stronger policy incentives in favor of the public input. The result is an increase of the income share of manufacturing, and declines in the shares of the other two production activities. There is also a substantial positive effect on total GDP and production levels. In particular, GDP per capita goes up by 10 percent. The increase in the amount of output produced is especially strong in the manufacturing sector, due to its important role in capital accumulation, and the larger efficiency of smaller firms that operate under diminishing returns to private inputs.

Second, we study the case when the increase in public capital formation occurs due to the improvement in the management of public investment so that a larger fraction of public investment expenditures ends up converted in public capital. Compared to the previous scenario, the GVA sectoral shares do not change much, because the same amount of investment goods can now generate stronger capital accumulation. The effects on GDP and sectoral production, though, remain substantial.

Third, we examine a variation in rent-seeking behavior of the central government directed to capture total output, which appears to have no effect on the paths of public capital accumulation, sectoral GVA, and GDP per capita. This is because rent-seeking politicians prefer that the economy achieves the first-best so that they can extract the maximum amount of rent. Fourth, we investigate the effect of a reduction in the effectiveness of public capital in specific sectors. Even though this does not significantly affect income shares, it has a clear

6

negative effect on the development process through a reduction in the optimal infrastructure stock. Finally, negative effects on GDP per capita and a possible reduction in the size of the manufacturing sector are also obtained in a scenario equivalent to a subsidization of public capital services that bring a decline in infrastructure investment.

Our paper contributes to the extensive literature on the structural transformation by proposing a novel driving mechanism that works through the supply side, and that directly affects both the productivity of private inputs and the firm's operating costs. Previous papers largely focus on two main channels of structural transformation. The first one is non-homotheticity of consumers' preferences, pioneered by Konsamut, Rebelo, and Xie (2001).[5] These authors build a neoclassical model of growth in which the income elasticity of demand is less than one for agricultural goods, equal to one for manufacturing goods, and greater than one for services. They are able to generate a balanced growth that is consistent with observed structural change trends. The second one is the sector-biased technical change suggested by Baumol (1967) and, more recently, by Ngai and Pissarides (2007).[6] Ngai and Pissarides (2007) show that if there are two industries, one characterized by a larger total factor productivity (TFP) growth, hours of work increase in the stagnant sector if the two goods have a relatively large degree of complementarity; otherwise labor moves in the direction of the progressive sector.

Several papers propose alternative mechanisms of structural transformation. Caselli and Coleman (2001) assume that non-agriculture sectors are more skill intensive than the agriculture sector. Bar and Leukhina (2010) and Leukhina and Turnovsky (2016) investigate the effects of population size increases. Alvarez-Cuadrado et al. (2016) point out that relative sectoral output prices also depend on the elasticity of substitution between capital and labor. Uy et al. (2013) and Tegnier (2016), among others, study the effect of openness to

---

[5]Similar demand-side channels are presented in Matsuyama (1992), Echevarria (1997), Laitner (2000), and Gollin et al. (2002), among others.

[6]Buera and Kaboski (2009) and Guillo et al. (2011) also provide support in favor of the biased technical change. So does Alonso-Carrera et al. (2017) regarding the main driving force of the movement of labor out of agriculture; however, this last paper finds as well that the increase of labor employment in the service sector is mainly caused by demand-side income effects.

international trade on the structural transformation. Finally, our paper is closely related to Acemoglu and Guerrieri (2008), who study a model based on capital accumulation and constant returns to scale; like us, Acemoglu and Guerrieri offer a supply-side explanation of structural change that depends on sectoral capital-intensity differences. None of these studies considers the role of public capital, neither a role of firm size heterogeneity in the structural transformation process.

There is at least another strand of the literature related to our work. It focuses on the role of transport costs on the spatial distribution of economic activity and income per capita. Herrendorf et al. (2012), for instance, study the effect of the transportation technology revolution on the spatial reallocation of labor between agriculture and manufacturing in the U.S. economy during the period 1840-1860. Another example is Karadiy and Korenz (2017), which quantify the impact of transport costs on sector location and productivity differences across OECD nations. Unlike us, these papers employ spacial static models, and focus on a different role of infrastructure.[7]

The rest of the paper is organized as follows. The next section presents the model outline. Section 3 studies a particular case that delivers a balanced-growth path, although without structural transformation. Section 4 describes the Brazilian experience and data that are further used to calibrate the model. Section 5 shows the results of the quantitative analysis and policy simulations. Section 6 concludes.

---

[7]There exists as well an important literature on the implications of public infrastructure provision on economic growth and development. Going back at least to Barro (1990), theoretical models have analyzed the possible role of public capital to long-run economic growth; contributions in this area include Glomm and Ravikumar (1994), Agénor (2010, 2012), and Rioja (2001), among others. Within an endogenous growth model, Felice (2016) studies the effect of public infrastructure on economic growth and the allocation of labor between a traditional and a modern sector. Other papers, like Chakraborty and Lahiri (2007) and Cubas (2017), try to quantify the impact of public capital on income differences across nations following a development accounting approach.

2 The Environment

We consider an economy with three main actors: households, firms, and the government. There are three production sectors: agriculture, manufacturing, and services; manufactures are the numeraire. For simplicity, we assume that there is a free international movement of capital. All other markets are closed.[8] Within all production activities, there is free entry and exit of heterogeneous firms. Firms pay fixed costs of entry and operation. If they decide to operate in the market, firms have access to a production technology that employs private capital, labor and public infrastructure, which are assumed imperfect substitutes in the production process. The public input determines factor productivity and affects the fixed costs faced by firms. Its nature is non-rival and its efficiency can vary across sectors.[9] It is provided by rent-seeking politicians and is financed by lump-sum consumer taxes. The model variables and parameters are described in appendix A.

2.1 Households

The economy is composed of infinitely-lived individuals that show preferences defined over public goods provided through government infrastructure (G_t) and consumption of agricultural goods (c_a), manufacturing products (c_m), and services (c_s). They are endowed with *one* unit of time that is supplied inelastically as labor in exchange for a salary (w_t). They own equal shares in all firms that provide dividends from profits each period (d_t). The population is a mass of size one and remains constant.

---

[8]The closed-economy assumption is common in the structural transformation literature. Openness in goods markets is introduced by some papers, like Uy et al. (2013), to accelerate the development of the manufacturing sector. In our case, the openness of capital markets simply implies that the interest rate is exogenous, and then the consumption side does not play any role in capital accumulation.

[9]We make the non-rivalness assumption to avoid unnecessary modeling complications. In real life, some types of public capital such as roads, electricity, and telecommunication networks have some degree of rivalness because of congestion issues. We elaborate on the possible consequences of relaxing this assumption in footnote 11.

The problem faced by a representative consumer is the following:

$$\underset{\{c_{it}, b_{t+1}\}}{Max} \left\{ \sum_{t=0}^{\infty} \rho^t \left[ln(c_t) + \mu \, ln(G_t^{\beta_c} p_{st} Y_{st}) \right] \right\} \tag{1}$$

where

$$c_t = \left[\omega_a^{\frac{1}{\varepsilon}} c_{at}^{\frac{\varepsilon-1}{\varepsilon}} + \omega_m^{\frac{1}{\varepsilon}} c_{mt}^{\frac{\varepsilon-1}{\varepsilon}} + (1 - \omega_a - \omega_m)^{\frac{1}{\varepsilon}} c_{st}^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2}$$

subject to the budget constraint

$$w_t + d_t + b_t(1 + r_t - \delta_k) - \tau_t = p_{at}c_{at} + c_{mt} + p_{st}c_{st} + b_{t+1}. \tag{3}$$

In the above problem, $\beta_c > 0$ allows for diminishing returns in the flow of utility obtained by households from public goods, the parameter $\varepsilon \in (0, \infty)$ represents the elasticity of substitution between goods in consumption, $\mu > 0$ weights the importance of public goods in preferences, so does ω_i with sector i in the consumption bundle c_t, ρ is the subjective discount factor, and Y_{st} is the real production by the service sector at date t. The prices p_{at} and p_{st} correspond to agricultural products and services, respectively, and are expressed in terms of manufacturing output. The consumer's stock of bonds in period t equals b_t, and provides a return given by the interest rate r_t minus the depreciation rate of private capital δ_k. Each individual pays lump-sum taxes τ_t to the government.

The contribution of public goods to the household's utility interacts with the GVA generated by the service sector. The idea behind this formalization is that the demand for public goods such as police, firefighters, water, and sanitation rises with the size of cities, as Buettner and Holm-Hadulla (2013) show for example; and that the average size of cities (proxied by the country's urbanization rate) is strongly positively correlated with income per capita – see, e.g., Gollin et al. (2016). Hence, for the sake of mathematical tractability, we proxy income per capita in the utility function using the size of the service sector, which grows monotonically with income per capita in all economies (Herrendorf et al., 2014).

Taking prices, public capital and the size of services exogenously, the solution to this problem results in the following optimality conditions for consumption:

$$\frac{P_{c,t+1}c_{t+1}}{P_c c_t} = \rho\left(1 + r_{t+1} - \delta_k\right), \tag{4}$$

$$\frac{p_{it}c_{it}}{P_{ct}c_t} = \omega_i\left(\frac{p_{it}}{P_{ct}}\right)^{1-\varepsilon}; \tag{5}$$

where the exact CES price of the consumption bundle equals

$$P_{ct} = \left(\sum_{i=a,m,s}\omega_i p_{it}^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}. \tag{6}$$

Equations (4) and (5) represent the intertemporal and the intersectoral optimality conditions for consumption, respectively. The former defines the growth rate of total consumption expenditure as a function of the return to saving, that is, the interest rate net of depreciation discounted to take into account the time preference. The latter, in turn, says that the share of sector i in total consumption expenditure depends on the weight ω_i and the relative price p_{it}/p_{ct}. More specifically, if the different consumption goods are complementary (i.e., $\varepsilon \in (0,1)$), the consumption share of sector i rises with its relative price; the opposite is true when the goods are relative substitutes, $\varepsilon > 1$; finally, if ε equals one, the share is constant and equal to its exogenous weight in the consumption bundle.

2.2 Firms

There is free entry and exit of profit-maximizing firms in all markets. These markets are perfectly competitive. We consider an unlimited number of potential entrants. Entrants have highly idiosyncratic specialization and can operate in one and only one sector during their productive lives. Establishments can generate output in activity $i = a, m, s$ combining labor services l_i, private capital k_i, and public infrastructure G. The production technology at the firm level displays diminishing returns over private capital and labor. Infrastructure is

supplied free of charge by the government,[10] and represents a non-rival good whose stock is used simultaneously by all firms.[11] Total factor productivity depends on a sector-specific parameter A_i that grows at the exogenous gross rate Z_{A_i} and a plant-specific efficiency coefficient q. As in Ngai and Pissarides (2007), sector-biased technical change – that is, differences in the growth rate of A_i across sectors – will be one source of the structural transformation in our model.

More specifically, the amount of output $y_{it}(q)$ produced by a firm that operates in sector i at time t as a function of q is given by the following technology:

$$y_{it}(q) = A_{it} q \left(e_{it} G_t\right)^{\beta_i} \left[k_{it}(q)\right]^{\alpha} \left[l_{it}(q)\right]^{\gamma}, \qquad \alpha, \beta_i, \gamma \in (0, 1); \qquad \alpha + \gamma < 1; \qquad (7)$$

where β_i represents the intensity with which public capital is used in sector i; whereas e_{it} is an exogenous sector-specific infrastructure-efficiency variable. The variable e_{it} captures the productivity of public capital for the different sectors; it can be related to its type but also its location. For example, relatively low levels of public investment in irrigation systems and lack of proximity of roads and electric networks to rural areas could mean a lower value of e_{at} compared to e_{mt}. This is different than the intensity with which irrigation systems are used in agriculture, which is clearly higher than in manufacturing.

Knowing its production function, expression (7), a profit-maximizing firm with efficiency q rent capital and labor until input prices are equalized to the value of their marginal pro-

---

[10]Infrastructure in the real world is not always provided free of charge. For example, electricity or telecom access fees set by state-owned enterprises in many developing countries can be quite high. Even if infrastructure provision is nominally free, there can be high shadow costs, such as long wait times to obtain a connection. In our model, these expenditures are captured, at least in part, by the fixed operation costs faced by firms, expression (15).

[11]We could relax this latter assumption and introduce congestion in the use of public goods, for example by dividing the stock of public capital G_t in expression (7) by the level of production $y_{it}(q)$. The main consequence would be the division by $1 + \beta_i$ of the input shares (exponents) in the reduced-form production function. As we do not impose constant returns over private inputs, the calibration exercise should take care of this possible effect of congestion.

ductivity. These first order conditions are given by:

$$w_t = p_{it}\gamma A_{it}q \left(e_{it}G_t\right)^{\beta_i} \left[k_{it}(q)\right]^{\alpha} \left[l_{it}(q)\right]^{\gamma-1}, \tag{8}$$

and

$$r_t = p_{it}\alpha A_{it}q \left(e_{it}G_t\right)^{\beta_i} \left[k_{it}(q)\right]^{\alpha-1} \left[l_{it}(q)\right]^{\gamma}. \tag{9}$$

Combining (7), (8) and (9) obtains that all firms will employ the same capital-labor ratios and that labor demand, capital demand and profits are a function of prices, total factor productivity and the infrastructure efficiency level:

$$\frac{k_{it}(q)}{l_{it}(q)} = \frac{\alpha w_t}{\gamma r_t}, \tag{10}$$

$$l_{it}(q) = \left[p_{it}A_{it}q \left(e_{it}G_t\right)^{\beta_i} \left(\frac{\gamma}{w_t}\right)^{1-\alpha} \left(\frac{\alpha}{r_t}\right)^{\alpha}\right]^{\frac{1}{1-\alpha-\gamma}}, \tag{11}$$

$$k_{it}(q) = \left[p_{it}A_{it}q \left(e_{it}G_t\right)^{\beta_i} \left(\frac{\gamma}{w_t}\right)^{\gamma} \left(\frac{\alpha}{r_t}\right)^{1-\gamma}\right]^{\frac{1}{1-\alpha-\gamma}}, \tag{12}$$

and

$$\pi_{it}(q) = (1 - \alpha - \gamma) \left[p_{it}A_{it}q \left(e_{it}G_t\right)^{\beta_i} \left(\frac{\gamma}{w_t}\right)^{\gamma} \left(\frac{\alpha}{r_t}\right)^{\alpha}\right]^{\frac{1}{1-\alpha-\gamma}}. \tag{13}$$

The last equality implies that the amount of profits $\pi_{it}(q)$ is a fraction $1 - \alpha - \gamma$ of total production of a type-q firm in sector i at time t.

Following Restuccia and Rogerson (2008), we assume that establishments are heterogeneous in terms of their TFP due to the plant-level productivity parameter q drawn from a distribution with density function $h(q)$, and that draws are i.i.d. across entrants. In order to learn q in period t, the firm needs to pay an exogenous fixed cost F_{qt}. In addition, after knowing their type, firms that want to operate in market i must pay a second sector-specific fixed cost F_{oit} that depends on the amount of infrastructure in the economy. In particular,

$$F_{qt} = f_q A_{mt}^{\psi}, \tag{14}$$

and

$$F_{oit} = f_{oi} A_{mt}^{\psi} \left(\frac{K_t}{G_t} \right)^{\theta}; \tag{15}$$

where the parameters $\theta, \psi > 0$ affect the response of the fixed costs to technological change and the relative supply of public capita, respectively; K_t is the total stock of capital in the economy at t; and f_q and f_{oi} are scaling parameters. Variables F_{qt} and F_{oit} are expressed in units of manufacturing output. In addition, F_{qt} implicitly incorporates an insurance premium that covers firms that decide to enter but that eventually, due to a bad draw of q, cannot pay F_{qt} fully after production occurs.

Equations (14) and (15) imply that fixed costs depend on the economy's technological level, captured by A_{mt}. Fixed costs will then increase with the level of development, a prediction consistent with the evidence presented by Bollard et al. (2016), among others. An example of F_{qt} is the cost of a market analysis intended to study the opportunities that the sector offers, and the strengths and weaknesses of the potential entrant within that market segment. Examples of F_{oit}, in turn, include any barrier to the operation that imposes a cost that rises with the ratio of private to public capital. These costs can be direct, like interest payments, depreciation, and maintenance of some indivisible equipment such as electricity self-generators, water tanks or satellite radio licenses, also permits, bribes and other indivisible administrative costs related to infrastructure access. They can be as well indirect, due for example to power outages, telecommunication network failures, or disruptions of water supply that prevent production while they occur. For the sake of simplicity, we assume that firms mutate and every period need to rediscover their type; that is, both costs need to be paid every period after production takes place.[12]

---

[12]Papers in the literature usually assume that the entry cost F_{qt} is only paid in the period of entry; see, e.g., Restuccia and Rogerson (2008). We do not follow their approach to avoid keeping track of the productivity level of incumbents that entered the market in previous periods. This assumption should not have a significant effect on our results.

Free entry means that establishments will enter the market if and only if expected profits are not lower than the up-front costs. This means that, before knowing its type, expected profits net of entry and operation costs in each sector i are reduced to zero. Therefore, the free entry condition can be stated as follows:

$$\int_0^\infty \left[\pi_{it}(q) - F_{oit}\right] h(q) \, dq - F_{qt} = 0;$$

(16)

In addition, after they know the type, firms will operate in a given period provided that they can obtain positive profits, which requires that their plant-specific productivity parameter q is greater than or equal to the threshold value $\hat{q}_{it}$ such that

$$\pi_{it}(\hat{q}_{it}) - F_{oit} = 0.$$

(17)

From free entry conditions (16), we can write output prices as

$$p_{it} = \frac{A_{mt} \left(e_{mt}G_t\right)^{\beta_m}}{A_{it} \left(e_{it}G_t\right)^{\beta_i}} \left[\frac{f_q + f_{oi}\left(\frac{K_t}{G_t}\right)^\theta}{f_q + f_{om}\left(\frac{K_t}{G_t}\right)^\theta}\right]^{1-\alpha-\gamma}.$$

(18)

Unlike the more standard multisector models with Cobb-Douglas production functions, where output prices are fully pinned down by relative TFP, the price in our framework depends on the variables that affect the relative productivity of private inputs – namely, the sector-specific productivity and the efficiency level of infrastructure – and on the relative size of fixed costs. A relatively less productive industry or a sector that faces higher relative fixed costs will charge a higher price. It is also easy to prove that a larger value of G_t will tend to increase p_{it} if $\beta_m > \beta_i$ due to the productivity effect (first quotient in the right-hand side of expression (18)), and if $f_{om} > f_{oi}$ because of the fixed-costs effect (second term inside brackets in the right-hand side of (18)). Therefore, since the evolution of relative prices represents a main determinant of the structural transformation, public capital can be an important force

15

in this process.

Taking on-board the last expression, along with conditions (8) and (10), it is also easy to derive the relative labor allocations. Within sectors, labor is allocated exclusively based on the efficiency parameter q as follows:

$$\frac{l_{it}(q)}{l_{it}(q')} = \frac{q}{q'}, \quad for \ i = a, m, s. \tag{19}$$

Firms with a larger productivity parameter q will hire more labor and rent more capital. Across sectors, in turn, the relative labor allocation obeys:

$$\frac{l_{it}(q)}{l_{mt}(q)} = \left[\frac{f_q + f_{oi}\left(\frac{K_t}{G_t}\right)^{\theta}}{f_q + f_{om}\left(\frac{K_t}{G_t}\right)^{\theta}} \right]^{1-\alpha-\gamma}. \tag{20}$$

for $i = a$, s. That is, across industries, variation in the hired amount of labor is exclusively driven by differences in fixed costs; sectors with lower fixed costs will have smaller firms on average.

The minimum plant-productivity level that justifies operation in sector i can be also easily obtained from (16) and (17) combining the free entry condition in manufacturing and the operation conditions. We obtain

$$\hat{q}_{it} = \left\{ \frac{E\left[q^{\frac{1}{1-\alpha-\gamma}}\right]}{1 + \frac{f_q}{f_{oi}\left(\frac{K_t}{G_t}\right)^{\theta}}} \right\}^{1-\alpha-\gamma}. \tag{21}$$

The expected value of $q^{\frac{1}{1-\alpha-\gamma}}$ ($E[q^{\frac{1}{1-\alpha-\gamma}} = \int_0^{\infty} q^{\frac{1}{1-\alpha-\gamma}} h(q) \, dq]$) and the fixed costs are its main determinants. To understand this, observe that the threshold value is related to the minimum firm-size that can survive in the market. A larger expected q makes fixed costs relatively less important in the entry decision and increases the size of the average firm. A larger sector-specific cost of operation, on the other hand, demands a larger size.

Finally, the profits that firms are able to obtain can be written as a function of the fixed

16

costs and the plant productivity index, because the last two variables determine the firm's size. Combining equations (13) to (16) and (21) yields

$$\pi_{it}(q) = (1 - \alpha - \gamma) \left(\frac{q}{\hat{q}_{it}} \right)^{\frac{1}{1-\alpha-\gamma}} F_{oit}. \tag{22}$$

Equation (22) implicitly reminds us that, at the minimum, firms' output must cover the fixed costs of operation. It also implies that profits before fixed costs depend on the ratio of the plant productivity level to its threshold value, $\hat{q}_{it}$. Therefore, to cover the entry costs F_{qt} and obtain strictly positive net profits, this ratio needs to be sufficiently larger than one.

2.3 The government

Consistent with the experiences of many developing countries, we assume that the public sector is an infinitely-lived institution composed of rent-seeking politicians that have their own preferences and do not optimally manage the economy. Politicians choose the amounts of rent capture, R_t, and public infrastructure spending, G_t, to maximize a welfare function that weighs the present value of consumers' utility and politicians' rent. In order to concentrate only on the variables that are under the direct control of the government – that is, R_t and G_t – we assume that the government makes decisions taking market allocations of other variables as given.

In particular, its problem can be written as follows:

$$\max_{\{R_t, G_{t+1}\}} \left\{ \varphi \, ln(R_t) + \sum_{t=0}^{\infty} \rho^t \left[ln(c_t) + u \, ln(G_t^{\beta_c} p_{st} Y_{st}) \right] \right\}; \tag{23}$$

where $\rho \in (0,1)$ is the time-preference coefficient; and $\varphi \geq 0$ weights the relative importance of rents. As a way to justify that equation (23) places value only on current rents extraction, we assume that politicians stay in the office for only one period; alternatively, we can think that politicians strongly believe that their corrupt behavior might not be sustainable in the near future.

The government's objective function (23) is maximized subject to the economy's feasibility condition:

$$\sum_{i=a,m,s} p_{it} Y_{it} = \sum_{i=a,m,s} N_{it} \left(F_{oit} + F_{qt} \right) + P_{ct} c_t L_t + I_{kt} + I_{gt} + R_t; \tag{24}$$

where N_{it} is the number of firms that produce output in sector i; I_{gt} and I_{kt} are investment in public infrastructure and private capital, respectively; and Y_{it} is aggregate output in sector i, given by

$$Y_{it} = N_{it} \int_{\hat{q}_{it}}^{\infty} y_{it}(q) h(q) \, dq. \tag{25}$$

Equation (24) says that the total production (i.e., GDP) is allocated to pay for the fixed costs, consumption, investment, and rent capture. Observe that this equation also represents the government's budget constraint, because it implies that the amount paid by consumers as taxes τ_t – production less fixed costs, private investment, and consumption – is allocated between public capital formation and rent extraction.

Following Darla-Norris et al. (2012), we assume that the government suffers from mismanagement of public investment. In particular, one unit of I_{gt} delivers $\xi < 1$ units of public-capital value (e.g., due to local corruption, indolence, or lack of public management skills). In a similar vein as Tabellini and Alesina (1990), we also suppose that because of its own preferences (or political ideology) the policy maker has a subjective valuation of the constructed public capital that is the result of rescaling the actual stock of public infrastructure using a parameter denoted by $\lambda > -1$. This might be the case, for example, because public goods benefit both groups that support the government and groups that do not; but the government cares more about the former ones. Unlike ξ, the ideology parameter λ does not diminish the economic value of public capital accumulation obtained per unit of I_g. Observe that whereas a lower ξ tends to lead the economy toward too much public investment (with relatively small capital formation) due to the larger degree of mismanagement, a lower λ will tend to cause too little public investment due to the lack of incentives.

These considerations create a gap between the actual motion of aggregate public infras-

tructure, and the subjective perception of the evolution of useful capital that the government takes into account to determine its optimal behavior. In particular, investment I_{gt} serves the maintenance and construction of infrastructure according to the following motion equation:

$$G_{t+1} = (1 - \delta_g)G_t + (1 + \mathbb{I}_\lambda \lambda)\xi I_{gt}; \qquad (26)$$

where $\mathbb{I}_\lambda$ is an indicator that takes on one when the the policy maker searches for the value of G_t that maximizes its objective function, and zero when determining the evolution of the stock of public capital in the economy; and the parameter δ_g represents the depreciation rate of G_t.

The first order condition to the government's problem – given by expressions (23) to (26) – with respect to R_t predict that politicians' rents are a fraction φ of total aggregate consumption:

$$R_t = \varphi L_t P_{ct} c_t. \qquad (27)$$

The first order condition with respect to G_{t+1} provides the intertemporal condition:

$$\frac{P_{ct+1}c_{t+1}}{P_{ct}c_t} = \frac{\rho(1+\lambda)\xi}{G_{t+1}} \left[\beta_c \mu \, P_{ct+1}c_{t+1} + \sum_{i=a,m,s} (\beta_i p_{it+1} Y_{it+1} + N_{it+1}\theta F_{oit+1}) \right] + \rho \left(1 - \delta_g \right). \qquad (28)$$

Equation (28) gives the optimal evolution of total consumption expenditure from the government's viewpoint. Unlike in equation (4), where the consumer links intertemporal consumption to the return to saving, the policy maker in (28) relates consumption expenditure growth to the marginal return to public capital investment. The return that takes into account that a higher G_{t+1} increases the household's utility and private input productivity, reduces firms' fixed costs, and that not the whole amount of public investment translates into *productive* public capital due to either mismanagement or political ideology.

Putting together (4), (7), (8), (25), (9), (16), (17) and (28) yields

$$r_t - \delta_k = \frac{(1-\lambda)\xi}{G_t}\left[\beta_c\mu\, P_{ct}c_t + \sum_{i=a,m,s} N_{it}\left\{\beta_i\frac{\int_{\hat{q}_{it}}^{\infty} q^{\frac{1}{1-\alpha-\gamma}}h(q)}{(1-\alpha-\gamma)E\left[q^{\frac{1}{1-\alpha-\gamma}}\right]}(F_{qt}+F_{oit}) + \theta F_{oit}\right\}\right] - \delta_g.$$

(29)

Equation (29) can be interpreted as a non-arbitrage condition: the government invests in public capital until the return is the same as the one provided by the alternative type of investment. It is evident again that the stock of public infrastructure G_t affects the productivity of all firms in the economy, regardless of their sector, due to its non-rival nature. The productivity of infrastructure is thus larger than the one perceived by the individual firm. It is also clear that a larger degree of mismanagement of public funds (a lower ξ) or a stronger politicians' preferences against public capital investment (a higher λ) both lead to a decrease in public capital formation.

2.4 Market clearing

To close the model we need to specify the market clearing conditions. In the labor market, the supply is given by the total population, normalized to one for simplicity, whereas firms' demand is derived from equation (8). Hence, labor market clearing requires:

$$\sum_{i=a,m,s}\left[p_{it}A_{it}\left(e_{it}G_t\right)^{\beta_i}\left(\frac{\gamma}{w_t}\right)^{1-\alpha}\left(\frac{\alpha}{r_t}\right)^{\alpha}\right]^{\frac{1}{1-\alpha-\gamma}}N_{it}\int_{\hat{q}_{it}}^{\infty} q^{\frac{1}{1-\alpha-\gamma}}h(q)\,dq = 1;$$

(30)

Let us now turn to the funds market. The amount of domestic saving available in the economy equals $b_{t+1} - b_t$. However, as capital markets are open, the supply of saving can be considered unlimited because of the small-open economy assumption. Therefore, from the supply side of the market the only relevant information that we need is the constant interest rate given by the rest of the world. The demand side at the firm level is given by equation (9), which implicitly pins down investment in private capital formation, I_{kt}. Starting from

the motion equation of private capital, we can then write

$$K_{t+1} = (1 - \delta_k)K_t + I_{kt}, \tag{31}$$

which can be further disaggregated in

$$K_t = \sum_{i=a,m,s} \left[p_{it} A_{it} \left(e_{it} G_t\right)^{\beta_i} \left(\frac{\gamma}{w_t}\right)^{\gamma} \left(\frac{\alpha}{r_t}\right)^{1-\gamma} \right]^{\frac{1}{1-\alpha-\gamma}} N_{it} \int_{\hat{q}_{it}}^{\infty} q^{\frac{1}{1-\alpha-\gamma}} h(q) \, dq. \tag{32}$$

As regards product markets, we assume that policy makers capture rents from each sector in the same proportion as its share in the aggregate consumption expenditure. Market clearing then requires that production is allocated between private agents' consumption and firms' fixed costs in all sectors, and also to investment in manufacturing. We can write these conditions as follows:

$$p_{it} Y_{it} = (1 + \varphi) \, p_{it} c_{it} + N_{it} \left(F_{oit} + F_{qt}\right), \quad i = a, s; \tag{33}$$

and

$$Y_{mt} = (1 + \varphi) \, c_{mt} + I_{kt} + I_{gt} + N_{mt} \left(F_{omt} + F_{qt}\right); \tag{34}$$

where the consequences of I_{gt} on the economic value and actual motion of G_t are given by

$$G_{t+1} = (1 - \delta_g)G_t + \xi I_{gt}. \tag{35}$$

At the face value, equation (34) implies that investment originates entirely in the manufacturing sector. However, this is not supported by the data. For instance, since the year 2000, total investment is larger than the entire U.S. manufacturing sector. An increasing component of investment such as software comes at least in part from services. Consequently, later in the paper, when we get to the model simulation and quantify the size of the different

sectors, we will assign a fraction of capital formation to the service industry.[13] This means that condition (34) should be interpreted as saying that all investment goods are produced using the same technology as manufactures, regardless of origin. Even though this can potentially matter, its quantitative relevance should not be large because total investment is a relatively small share of GDP.

2.5 Equilibrium

We are focusing on a decentralized small open economy with public sector intervention that takes the world's interest rate r_t as given. An equilibrium in this model economy is defined as the value of wages w_t, input prices p_{it}, consumption c_{it}, investments x_{it}, private input allocations $l_{it}(q)$ and $k_{it}(q)$, infrastructure provision G_t, operation thresholds $\hat{q}_{it}$, number of firms N_{it}, and politicians' rents R_t so that, given input and output prices, consumers maximize utility, firms maximize profits, and the government maximizes its welfare function, and where prices are the solution to the free entry and market clearing conditions.

A useful transformation to study the dynamics of this economy is writing the capital-to-labor ratio, expression (10), in terms of aggregate capital as follows:

$$K_t = \frac{\alpha w_t}{\gamma r_t};$$

(36)

recall that the size of the labor supply is normalized to one. Expression (36) allows for constructing a solvable equation system that only depends on sectoral variables.

More specifically, for a predetermined stock of infrastructure and an interest rate given by the international market, free entry condition (16) for the manufacturing sector along with (36) pins down the equilibrium wage rate and the stock of private capital. Output prices and plant-productivity thresholds are given by (18) and (21), respectively. Incorporating (5) and (6) into the market clearing conditions makes equations (30) and (33) deliver expressions

---

[13]The share of the agriculture sector in total investment is not significant and thus ignored in model simulations.

for the number of firms in each industry. Finally, motion equations (31) and (35), market clearing condition in manufacturing (34) and the public-investment optimality condition, equation (29), solve for the optimal consumption and investment values.

The above method of solution provides all economy-wide and sectoral equilibrium values of the endogenous variables. In addition, these equilibrium values need to be compatible with the optimal path of aggregate consumption determined by intertemporal condition (4). Rents extracted by politicians can be recovered from (27). At the firm level, the capital and labor allocations are obtained from equations (10), (11), (19) and (20).

3 Balanced Growth without Structural Transformation

The model, in general, does not have a balanced growth path (BGP); not even if we exclusively ask economy-wide variables such as aggregate consumption and the stock of capital to have this feature, allowing the sectoral ones to show a non-constant growth rate. The reason is that, unlike in Ngai and Pissarides (2007) multisector growth model, the production function does not display constant returns over costly inputs (i.e., $\alpha + \gamma < 1$). In order to have a BGP, we would need to have the price P_{ct} of the consumption bundle grow at a constant rate at the steady state. We do not make this assumption because it would constrain the values that could be assigned to the parameters and the potential of the model to generate reallocations of resources among sectors. Nevertheless, it is interesting to look at the drivers of growth in this particular scenario to have a deeper understanding of the model. In addition, because in our simulations we focus on a path that is close to constant growth, some of the expressions that we develop next are useful for the calibration of the model parameters.

Let us denote by Z_x the gross growth rate of a variable x along the BGP, and assume that $Z_G^{\beta_m - \beta_i} Z_{A_m}/Z_{A_i} = 1$, for $i = a$, s, so that P_{ct} remains constant at the steady state. In this scenario, the economy converges towards a BGP in which the feasibility constraint (24) suggests that the sectoral variables (i.e., output value, private capital, and profits), the aggre-

gate variables (i.e., fixed costs, consumption, rents, public infrastructure, and investments) all grow at the same rate as Y_{mt}. In addition, it follows from the definitions of sectoral capital and output – expressions (25) and (32) – that the firm's output value and its capital stock will grow at the same rate as y_{mt} in all activities. According to equation (25), the difference between the growth rates of Y_{mt} and y_{mt} will be due to the growth rate of the number of firms, which by expressions (14) and (15) will take on the same number in all sectors. The salary w_t is an important variable that will grow at the same rate as aggregate income per capita.

We know that along the BGP $Z_G = Z_{Y_m}$. Equation (18), which also holds for the agriculture sector in the long-run equilibrium, then implies that the gross growth rate of output prices equals:

$$Z_{p_i} = \left(\frac{Z_{A_m}}{Z_{A_i}}\right) Z_G^{\beta_m - \beta_i};$$ (37)

an expression that equals *one* under our assumption. Observe that this suggests that output prices tend to compensate for productivity differences so that output revenues grow at the same rate across all sectors. Equation (37) along with the production function (7) and input demand equations (11) and (12) imply that

$$Z_{p_i y_i} = \left(Z_{A_m} Z_{Y_m}^{\beta_m - \gamma}\right)^{\frac{1}{1-\alpha-\gamma}}.$$ (38)

Next, observe that definition of sectoral output (25) requires that $Z_{p_i Y_i} = Z_{p_i y_i} Z_{N_i}$. Then, combining equations (14) and (15) result in

$$Z_{N_i} = Z_{A_m}^{\frac{1-(1-\alpha-\beta_m)\psi}{\gamma-\beta_m}},$$ (39)

$$Z_{y_m} = Z_{A_m}^{\psi},$$ (40)

and

$$Z_{Y_m} = Z_{A_m}^{\frac{1}{1-\alpha-\beta_m} + \frac{1-\alpha-\gamma}{\gamma-\beta_m}\left(\frac{1}{1-\alpha-\beta_m} - \psi\right)}.$$ (41)

Equation (39) shows that the growth rate Z_{N_i} depends primarily on how fast fixed costs increase: as the share of labor in production is the largest ($\gamma - \beta_m > 0$), the firm size will tend to increase if fixed costs grow slower than TFP ($\psi < \frac{1}{1-\alpha-\beta_m}$), and vice versa.

Given that, before knowing the firm´s type, free entry implies zero profits for the average potential entrant, the growth rate of production at the plant level is determined by the growth rate of fixed costs (equation 40). At the sectoral level, the aggregate production growth rate will be a combination of the previous two (equation 41). On the one hand, TFP growth will increase the growth rate of sectoral value added. Also observe that the effect of the TFP, given by the inverse of $1 - \alpha - \beta_m$, rises with the share of both types of capital in production. The evolution of fixed costs will be beneficial for economic growth as long as they increase more slowly than TFP; otherwise, they will reduce the growth of the economy.

Finally, the Euler equation for consumption informs about the interest rate, r_t, and the economy's growth rate that are compatible with consumers' preferences along the BGP. More specifically, at the steady state, it follows from equation (4) that

$$r_t = \frac{Z_{Y_m}}{\rho} - 1 + \delta_k; \tag{42}$$

Even though in our model the interest rate is given by the international market, equality (42) will prove useful later in the calibration.

4 Public Infrastructure and Structural Transformation in a Developing Country: The Case of Brazil

We study the model, and more specifically, the relationship between structural transformation and public infrastructure formation guided by the Brazilian experience. We focus on this middle-income Latin American nation because it is widely considered to be in deep need of further infrastructure investment. For example, the Global Competitiveness Report 2016-17

Figure 2: Sectoral shares of Brazilian GVA (left panel) and firms (right panel)
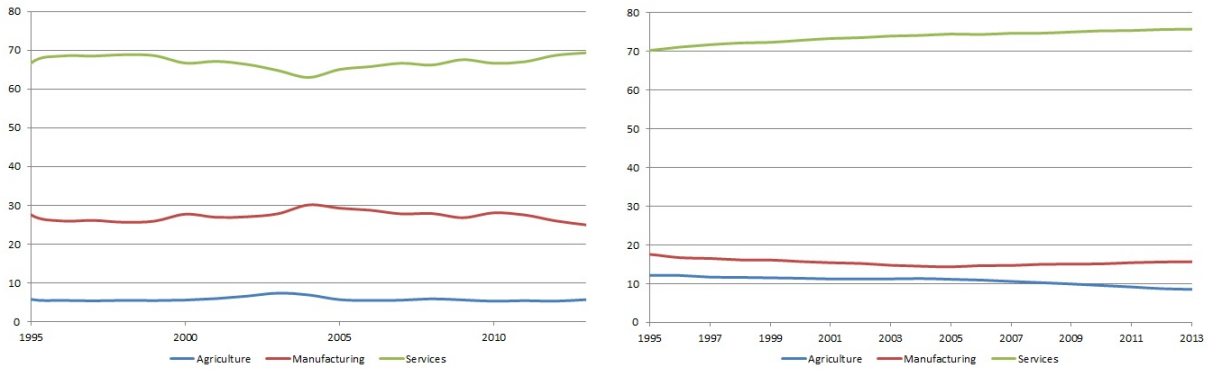
ranks Brazil's quality of overall infrastructure at 116th place out of 138 nations, two positions below its 2013-14 ranking. The quality of its roads is at 111th place, its railroads at 93rd, its ports at 114th, its air transport at 95th, and its electricity supply in 91st. The last figure represents a significant decline compared to the 76th position achieved in 2013-14.

In addition, in line with our model, Brazil's poor infrastructure status seems to be at least in part due to poor management of public investment. As Amann et al. (2016), among many others, argue, this is related to Brazil's deficient regulatory governance that has deterred or delayed infrastructure investment. World Bank (2012) gives a clear example of lost public capital as a consequence of bureaucratic barriers: no less than 15 to 20% of the budgets of hydroelectric investment projects in Brazil are a consequence of environmental licensing costs. Corruption is also behind the low quality of regulatory governance, with a prominent case of the Petrobrás contractors' scandal in 2014. Contractors of Petrobrás, the state-controlled oil firm, paid billions of dollars in bribes to political parties using corrupt intermediaries. Importantly, many contractors were also among Brazil's largest infrastructure builders. Ojo and Everhardt (2013) estimate that 124% more roads and 525% more railways could have been constructed between 2007 and 2010 in the absence of corruption.[14]

Finally, unlike many developing countries, Brazil offers a good quality, regionally and

---

[14]Though public management issues are important, Brazil is not an extreme case of mismanagement according to the public investment efficiency index developed by Dabla-Norris et al. (2012). With an index of 3.12 out of 4, it ranks second within their sample of 71 low- and middle-income nations.

sectorally disaggregated historical data on both public infrastructure an structural transformation variables that can be used to calibrate our model. The data we use comes from the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística*, IBGE), the Annual Report of Social Information (*Relação Anual de Informações Sociais*, RAIS), and the Institute of Applied Economic Research (*Instituto de Pesquisa Econômica Aplicada*, IPEA).

We focus on the time interval that starts in 1995 and ends in 2013.[15] Figure 2 plots the shares of the three main sectors – agriculture, manufacturing, and services – in GVA (left chart) and in the number of firms (right chart). The former variable is supplied by IBGE and the latter by RAIS. We see that, during the studied period, the services sector has experienced an increase from 66.7% to 69.3% in its value-added share, the manufacturing sector has declined from 27.5% to 25%, and the agriculture sector has remained relatively constant, moving from 5.8% to 5.7%. The share of firms depicts a similar pattern, although now agriculture also shows a significant change. In particular, the share of firms in both agriculture and manufacturing has fallen (from 12% to 9% in the former and from 18% to 16% in the latter), and in services has increased from 70% to 76%.

Let us now turn to the number of employees. Using data obtained from RAIS, Figure 3 shows its evolution across the economy sectors: the left panel looks at the absolute numbers, whereas the right one gives the sectoral shares.[16] The left panel shows that the total number

---

[15]In principle, we could access data for all the variables from 1985. However, before 1995 the numbers look odd. Figure 10 (Appendix B) plots the shares of agriculture, manufacturing and services in GVA (left panel) obtained from IBGE, and the number of firms (right panel) supplied by RAIS from 1985 to 1995. Before 1995 we observe some peculiar trends. In services, for example, the share of firms drops rapidly during this period, even though its GVA share grows probably too fast. Based on authors' conversations with IBGE staff there are three likely explanations for these distortions: (i) the strong hyperinflation suffered by Brazil between 1980 and 1994 that reached an annual inflation rate close to 3,000%, (ii) change in sector classification standards in 1995, and (iii) the data before 1995 were not based on representative sample of firms. A comparison of the IBGE income shares to the alternative numbers offered by the Groningen's 10-Sector Database also reinforces our time-period choice. In particular, the sectoral shares supplied by this alternative source of data are very different from the ones given by IBGE before 1995; however, the numbers are similar after that date.

[16]RAIS collects information only about the formal economy. Information on workers in the informal sector could be also obtained from the Continuous National Household Sample Survey (PNAD). We do not follow this approach, however, because PNAD does not offer data on the number of firms.

Figure 3: Number of employees (left panel) and sectoral employment shares (right panel)
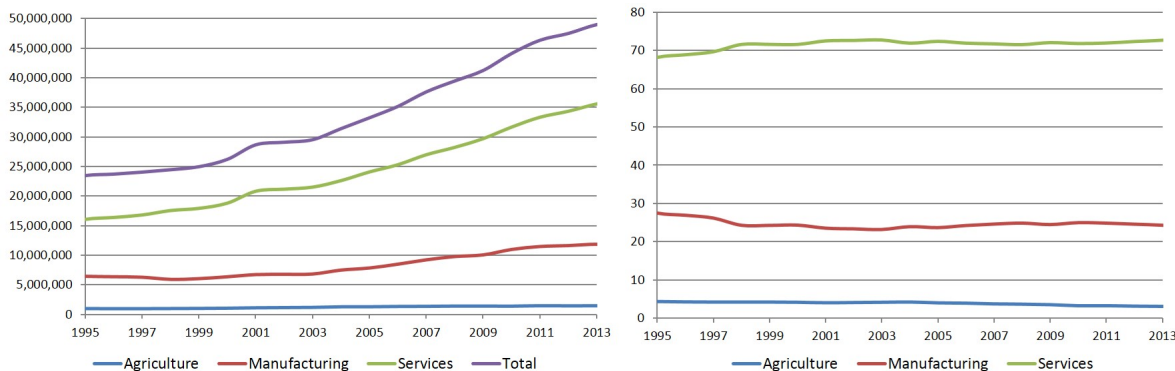
of workers in Brazil goes up from 23.5 million to 49 million between 1995 and 2013. The number of employees grows faster in the services sector, with an annual average growth rate of 4.6%. The same figure for the manufacturing sector is 3.5%, and 2.2% for the agriculture sector. The right panel, in turn, shows that the employment shares at the sectoral level follow relatively closely the evolution of the GVA ones. More specifically, the share of agricultural and manufacturing employment goes down from 4% to 3% and from 28% to 24% during the same time interval, respectively; whereas the one in services increases from 68% to 73%.

Figures 4 and 5 present, for each of the three sectors, the evolution in the distribution of firms and the distribution of employees per firm size, respectively. The distribution is derived for each five-year period between 1995 and 2014. Firm sizes are grouped into ten categories based on the number of employees (variable l_{it} in our model and then denoted by "lit" in the data legends). These categories go from zero employees, which means that only the owners provide labor services, to more than or equal to 1,000. In Figure 5 the category "lit = 0" does not appear because there are no hired employees in that group.

Focusing first on Figure 4, we see that the distribution looks log-normal in each of the three sectors. In addition, comparing across the four five-year intervals, there do not seem to be significant changes over time. Nevertheless, there are differences across industries. The agriculture sector has the largest share of small firms, whereas the manufacturing sector is the less skewed towards smaller firms. For example, for the 2010-14 interval, about 70% of

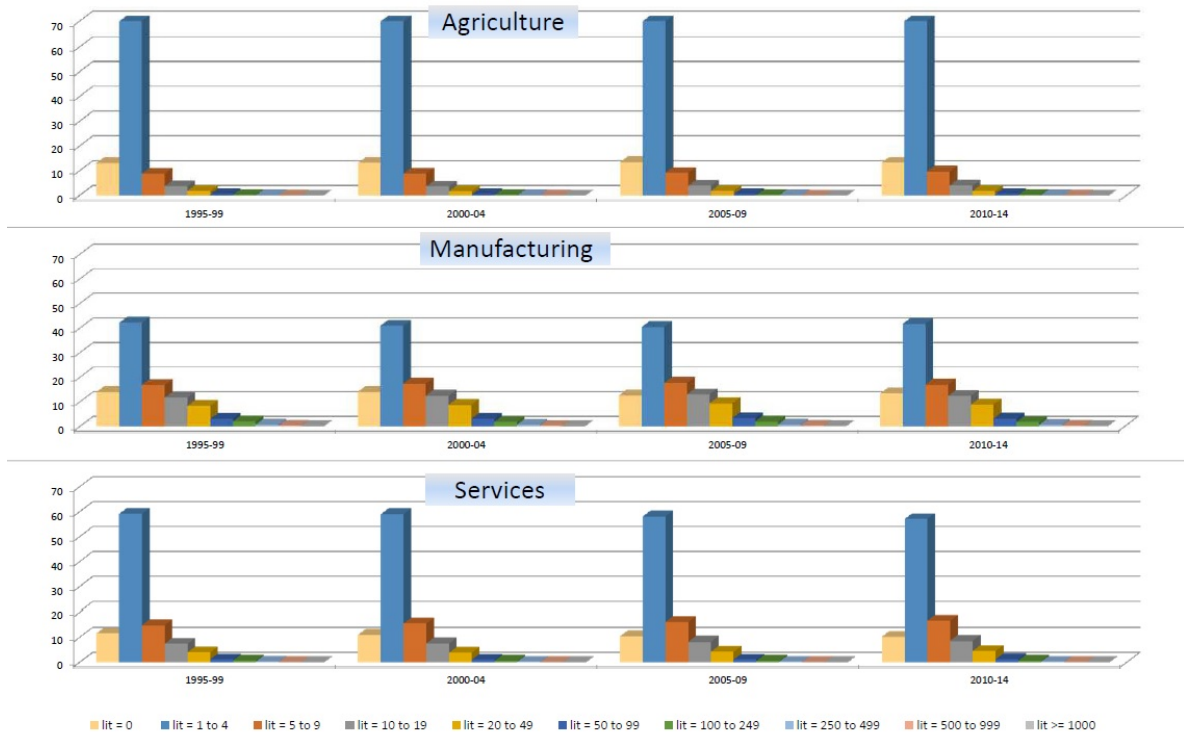Figure 4: Percentage of firms per firm size in each sector

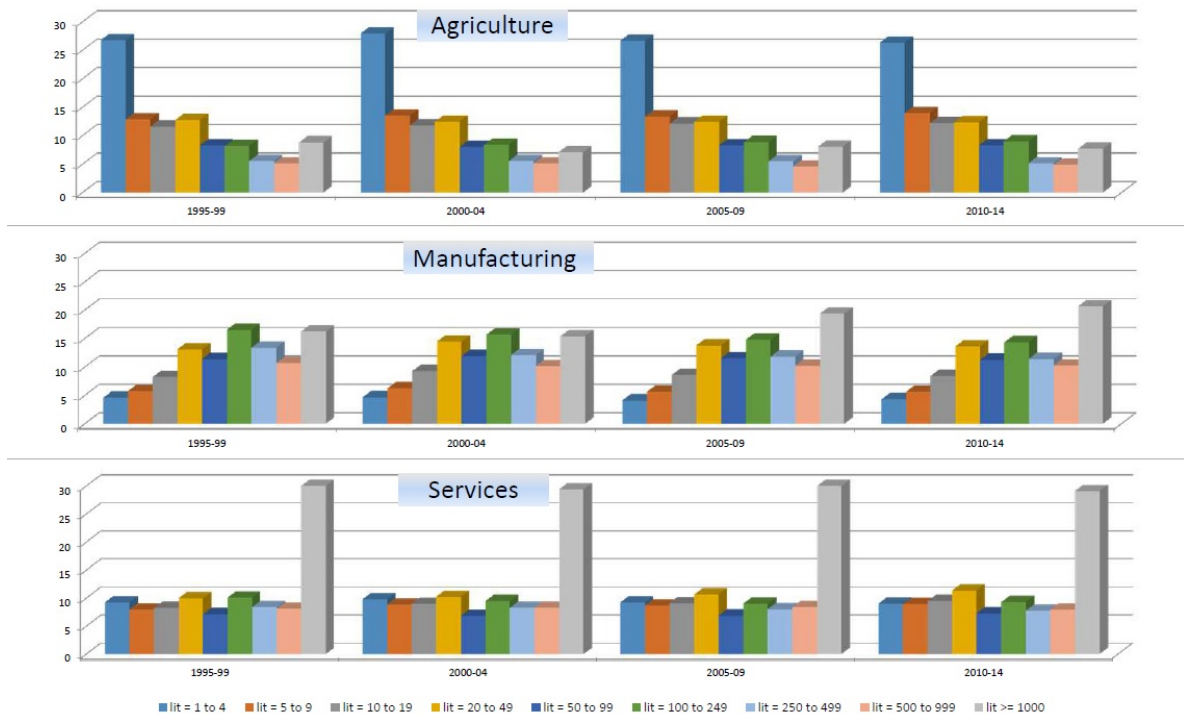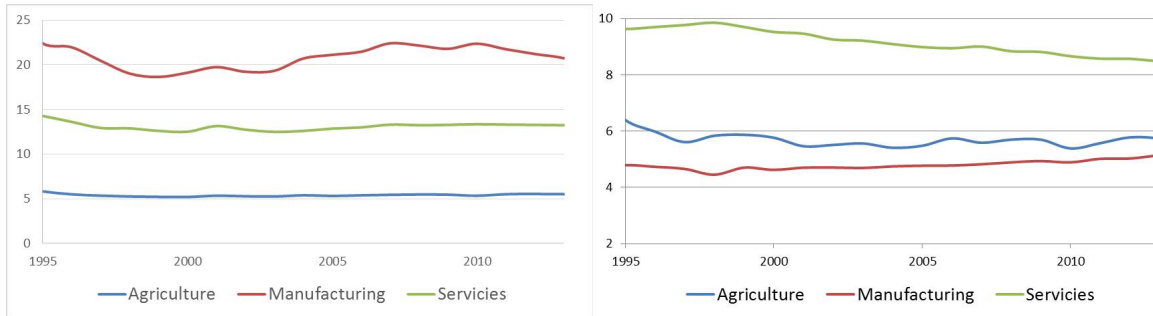Figure 5: Percentage of employees per firm size in each sector

Figure 6: Number of employees per firm: mean (left panel) and coefficient of variation (right panel)

firms in the agriculture sector have between one and four employees; this number compares to 42% and 57% in the manufacturing and services sectors, respectively.

Figure 5 does not show either significant changes over time in the distributions of employees. The exception is the manufacturing sector, where the share of workers in the group of firms with more than 999 employees increases from 16% to 21%; this increase occurs at the expense of firms in the categories between 100 and 499. Across sectors, on the other hand, we can observe important differences. Employment in the agriculture sector is concentrated in small firms, and the opposite occurs in the manufacturing sector. In particular, more than 50% of agricultural employees serve firms with fewer than 20 workers. This contrasts with the manufacturing sector, where firms with 100 employees or more hire almost 60% of workers in that sector. The services sector is an intermediate case, where workers are more evenly spread over the different categories than in the other two sectors. Interestingly, this is the case even though the largest employment category in the services sector accounts for a larger percentage of employment (29%) than in the manufacturing sector (21%).

Figure 6 plots two summary statistics of the previous distributions: the mean and the coefficient of variation of the number of employees. The left-hand-side panel depicts the evolution of the mean number of employees per establishment in each sector. The agriculture sector is the one with the smallest average firm, followed by the services sector; the largest average establishment is located in the manufacturing sector. More specifically, the average

for the period is 5.4 employees per plant in agriculture, 20.8 in manufacturing, and 13.1 in services. That is, the average size of a firm in the services and the manufacturing sectors is more than twice and four times as large as the one in the agriculture sector, respectively. A closer examination of the chart also tells that the average size does not seem to have a clear trend, even though over the period 1995 - 2013 there is a small decline in all sectors.

The coefficient of variation confirms the information obtained previously from Figure 5.[17] On the right panel of Figure 6, the most heterogeneous sector in terms of firm size is the services sector. In this sector, we also observe a substantial decline in the degree of heterogeneity from 1995 to 2913. According to Figure 5, this seems to be a consequence of the increase in the importance of middle size firms. Some reduction in the degree of heterogeneity can be also observed in the agriculture sector. Finally, although there is a small increase in the coefficient of variation in the manufacturing sector between 1996 and 2013, it remains the most homogeneous industry, with a bias towards larger firms.

5   Quantitative Analysis

This section first assigns values to the different parameters of the model. Several of these values are chosen so as to reproduce the evolution of sectoral variables in Brazil from 1995 to 2013. After that, we show the results of model simulations from policy experiments.

5.1   Calibration

Let us start with the parameters related to the household's behavior. We pick from the business cycle literature a standard value for the discount factor, $\rho = 0.96$. For the weights of the different sectors in consumption, we choose values similar to other studies like Betts et al. (2017), $\omega_a = 0.07$, $\omega_m = 0.15$. The elasticity of substitution between consumption goods comes from Herrendorf et al. (2009). Using a value-added approach and the U.S. data

---

[17]The coefficient of variation is calculated from data on the number of employees in each firm-size category assuming that, within categories, establishments have the same number of workers.

Table 1: Benchmark model parameterization and targets

Variables / Parameters	Values	Criteria / Targets
$\rho,\ \omega_a,\ \omega_m$	0.96, 0.07, 0.15	Standard in literature
ε	0.002	Herrendorf et al. (2009)
$r_t,\ z_{Am}$	0.0775, 1.023	GDPpc growth, Brazil, 1995-2013
$\alpha,\ \gamma$	0.283, 0.567	Restuccia and Rogerson (2008)
$\beta_a,\ \beta_m,\ \beta_s$	0.106, 0.044, 0.008	Melo et al. (2013, Table 4)
$e_i,\ \varphi,\ \lambda$	1, 0, 0	Normalization
$z_{Aa} = z_{As}$	1.001	Sectoral GVA shares, Brazil, 1995-2013
$A_{a1995},\ A_{s1995},\ A_{m1995}$	17.4, 43.4, 33.0	Sectoral GVA shares, Brazil, 1995-2013
$\delta_k,\ \delta_g$	0.05, 0.05/2 = 0.025	Private capital formation, Brazil, 1985-2009
θ	0.51	Public capital formation, Brazil, 1985-2009
ξ	0.60	Annual cost of corruption, Brazil, 2010
$\psi,\ \beta_c$	1.486, 0.08	Zero growth in number of workers per firm
$f_q = f_{os},\ f_{oa},\ f_{om}$	0.413, 0.127, 0.700	Number of workers per firm in each sector
$\frac{I_{kt} + I_{gt}}{GDP}$ assigned to services	0.27	Brazilian input-output tables, 2014

these authors estimate $\varepsilon = 0.002$. The balanced-growth path condition for consumption, equation (42), can be employed to proxy the international interest rate. An interest rate net of depreciation of 7.75% is the one compatible with the 3.4% annual growth rate of real GDP per capita for the Brazilian economy over the period 1995-2013 obtained with Penn World Tables data, version 8-0.

As we mentioned previously, not all investment comes from manufacturing because the service sector is an increasingly important component. Recall that our underlying assumption in equation (34) is that all investment goods are produced using the same technology as manufactures, regardless of origin. Next, we search for the share of investment that needs to be assigned to each of these two sectors. Following Herrendorf et al. (2014), we allocate investment value added to each sector using constant shares. As these authors argue, the quantitative relevance of these assumptions should be relatively small because total investment is a relatively small share of GDP. To estimate the share that we should attribute to services, we use input-output data for Brazil from the World Input-Output Tables, 2016 release. In 2014 the share of manufacturing in fixed capital formation was about 73%. Then, we assign the remaining 27% to services, and compute the share of agriculture, manufacturing and

services as $p_{at}Y_{at}/GDP_t$, $[p_{mt}Y_{mt} - 0.27(I_{kt} + I_{gt})]/GDP_t$ and $[p_{st}Y_{st} + 0.27(I_{kt} + I_{gt})]/GDP_t$, respectively.

On the production side, we adopt the values of Restuccia and Rogerson (2008) in a similar setting for the shares of private inputs; in particular, $\alpha = 0.283$ and $\gamma = 0.567$. Assigning values to the efficiency parameter of the public input in the different sectors is more complicated. We choose to follow Melo et al. (2013), who conduct a meta-analysis of the empirical evidence on the impact of transport infrastructure investment, the largest component of public capital (Fernald, 1999). Table 4 in their paper provides the following estimates: $\beta_a = 0.106$, $\beta_m = 0.044$ and $\beta_s = 0.008$.[18]

We carry out the following normalization: $\lambda = 0$, $e_i = 1$ for all i, and $\varphi = 0$. These parameters are related to the government, and our main interest is knowing how changes in their values affect the results. In the calibration of the remaining model parameters and in all the posterior experiments, we focus on scenarios that follow a sufficiently stable path in the sense that the growth rates of consumption expenditure, GDP, and capital stocks are (approximately) constant at the 3 digit level.[19] With this, we try to be approximately consistent with the Euler equation for consumption – given by expression (4) – when the interest rate is fixed. In addition, the seemingly constant growth of aggregate variables means as well that we concentrate on paths that are approximately consistent with both Kaldor and Kutznets facts.

The manufacturing-sector productivity growth rate is chosen also so as to reproduce the Brazilian average growth rate of GDP per capita. This implies $z_{Am} = 1.0227$. In turn, the growth rates of the sector-specific productivity parameters in the other two sectors and their

---

[18]Ideally, we would like to use the Brazilian data. The problem is that data on sectoral infrastructure are not readily available. Nevertheless, for the years 1970, 1975 and 1980, for each of the 26 Brazilian states plus the Federal District, we managed to get numbers in manufacturing and services for GVA and employed people from IBGE, and the capital stock in private firms and the capital stock in government-own enterprises from IPEA. Employing the latter capital as a proxy for public infrastructure and carrying a simple state-level OLS panel regression, we found $\beta_m = 0.050$ and $\beta_s = 0.014$; which are close to the ones obtained from Melo et al. (2013).

[19]For example, the growth rate could be fluctuating in the interval 0.0344 and 0.0336, and we would consider that the growth rate is approximately constant at 0.034.

initial values are chosen to reproduce the Brazilian sectoral shares of GVA in 1995 and 2013. This gives $A_{a1995} = 17.37$, $z_{Aa} = 1.001$, $A_{s1995} = 43.42$, $z_{As} = 1.001$ and $A_{m1995} = 33.00$.[20] The value assigned to the depreciation rate of private capital is the one that generates an average investment share in this private input in Brazil for the period 1985-2009 of 0.184, the number calculated from the IBGE data on the gross fixed capital formation.[21] Given that estimated depreciation rates for public capital are usually about half those of private capital (see, e.g., Kamps 2006) we obtain $\delta_k = 0.05$ and $\delta_g = 0.025$.

We saw previously that the average number of employees per plant has not changed much in Brazil from 1995 to 2013. This has two implications for our parameterization. First, as the population remains constant in our model, the constancy of the average firm size implies assuming that the number of establishments per sector is also constant; which requires a value of 1.486 for the parameter ψ. This value also corresponds to the one implied by equation (39) because the economy is close to constant growth in our simulations. Second, expression (20) demands that the ratio of K_t to G_t stays the same. Imposing this condition on our model requires $\beta_c = 0.08$, and the implied ratio of private to public capital is 3.9.

After the depreciation of public capital and the βs are chosen, the remaining parameter that determines the income share of public investment is θ, the elasticity of the fixed costs to the private-to-public capital ratio. The same source and time interval used above for its private counterpart provides the average value of the public-investment income share of 0.034. If we consider this share to be the investment that really contributes to capital formation, total funds allocated by the public sector to investment must equal this number plus the income lost due to mismanagement. According to FIESP (2010), the average annual cost of corruption in Brazil can be between 1.38 and 2.3% of the country's total GDP. Taking the latter figure as a conservative estimate, we have a total public investment share of 0.057.

---

[20]Hence, in our calibration, agriculture and services show slower TFP growth than manufacturing. Papers that have estimated TFP growth across sectors, however, like Herrendorf et al. (2015), among others, typically find that the agriculture sector is the one that experiences the fastest growth, followed by the manufacturing and the services sectors. In this respect, it is important to note that these papers compute the TFP as a residual from production functions that do not include public capital as an input.

[21]Disaggregated investment numbers are not available for later years.

Figure 7: Benchmark simulations and Brazilian data
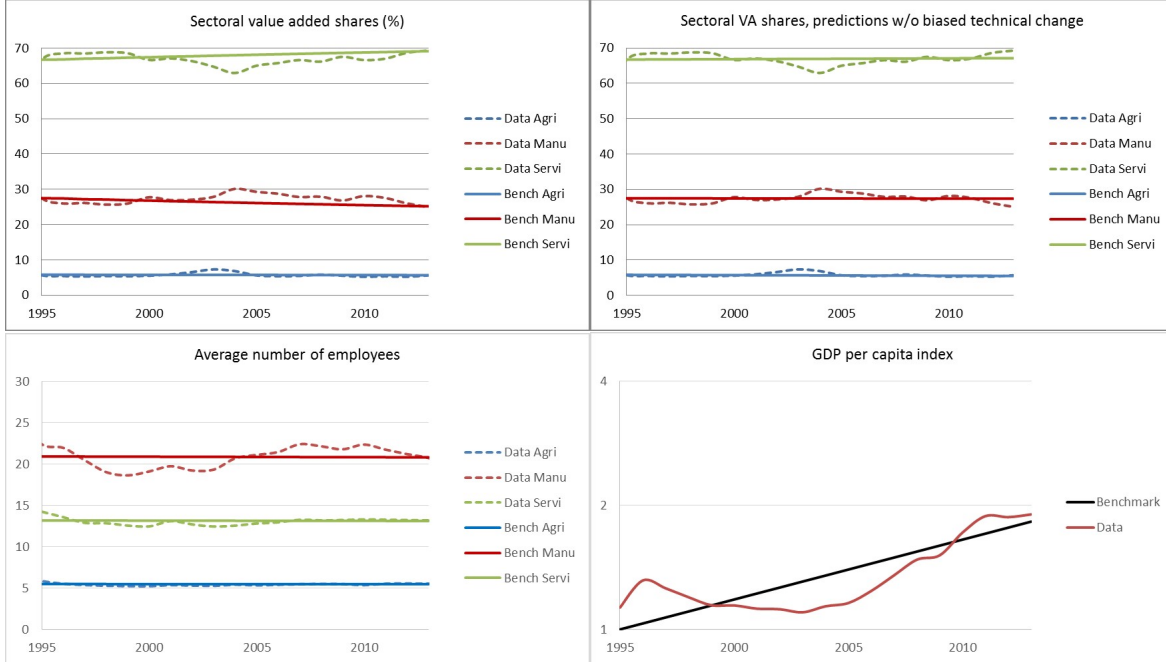
To obtain this number, we set $\theta = 0.51$. It also implies a value for the mismanagement parameter ξ of $0.034/0.057 = 0.60$.

Our remaining calibration task is to assign values to the four fixed-costs parameters that affect the number of employees per establishment. Targeting their average number in each of the three sectors in our Brazilian data sample leaves us with one degree of freedom at pinning down f_q, f_{oa}, f_{om} and f_{os}. To deal with this issue, we impose $f_q = f_{os}$ because the services sector shows an intermediate value. Under this assumption, we get $f_q = f_{os} = 0.413$, $f_{oa} = 0.127$ and $f_{om} = 0.700$.

5.2 Simulation Results

5.2.1 Model Baseline

We start by looking at the correspondence between the simulated predictions resulting from the benchmark parameterization and the Brazilian data with regards to sectoral value added shares, the average number of workers per firm in each sector, and the GDP. Figure 7 shows

simulated results. The top left panel shows the evolution of the sectoral GVA shares. We see that the model approximates well the data values at the beginning and at the end of the sample period. To understand the elements that contribute to this fit, we first note that we have assigned a value of 0.002 to ε, thus meaning that the three sectors are complementary. Therefore, from equation (5), we know that an increase in the relative price of a product will result in raising the income share of that sector. To see how output prices evolve, in turn, we need to look at equation (18). This expression implies that, according to our parameterization, TFP growth over the period 1995-2013 in Brazil pushed up the shares of the agriculture and the services sectors, because in both sectors the calibrated TFP growth rate is lower than in the manufacturing sector. In addition, the growth of the public capital stock induces two different effects. First, it shifts the structural transformation process in the direction observed in the data, increasing the share of services and reducing the share of agriculture relative to manufacturing, as a consequence of the relatively lower intensity of public capital in the services sector and the relatively higher one in the agriculture sector. Second, the growth in public infrastructure reduces fixed costs, but relatively more in the manufacturing sector. This means that, ceteris paribus, the income share of the secondary sector will decline as the public capital is accumulated, as a more rapid decline in fixed costs raises the relative prices in the other two sectors. However, this last effect is not significant in Figure 7 because we maintain the ratio of private to public capital approximately constant along the simulated path.

The top right panel in Figure 7 reinforces the above intuition. This chart assumes that technological change is not biased, and in particular, that $Z_{A_i} = 1.0227$ for all i. In other words, it elucidates the effect of a growing capital stock that works through differences in its efficiency across sectors. Even though in this scenario the predicted changes in the sectoral GVA shares occur relatively slow, in part due to the low Brazilian rate of public capital formation, the growth of G_t is able to explain 5% and 15% of the overall change in the manufacturing and the services sectors, respectively. In the case of the agriculture sector,

Figure 8: Comparative dynamics if λ rises to 1.64
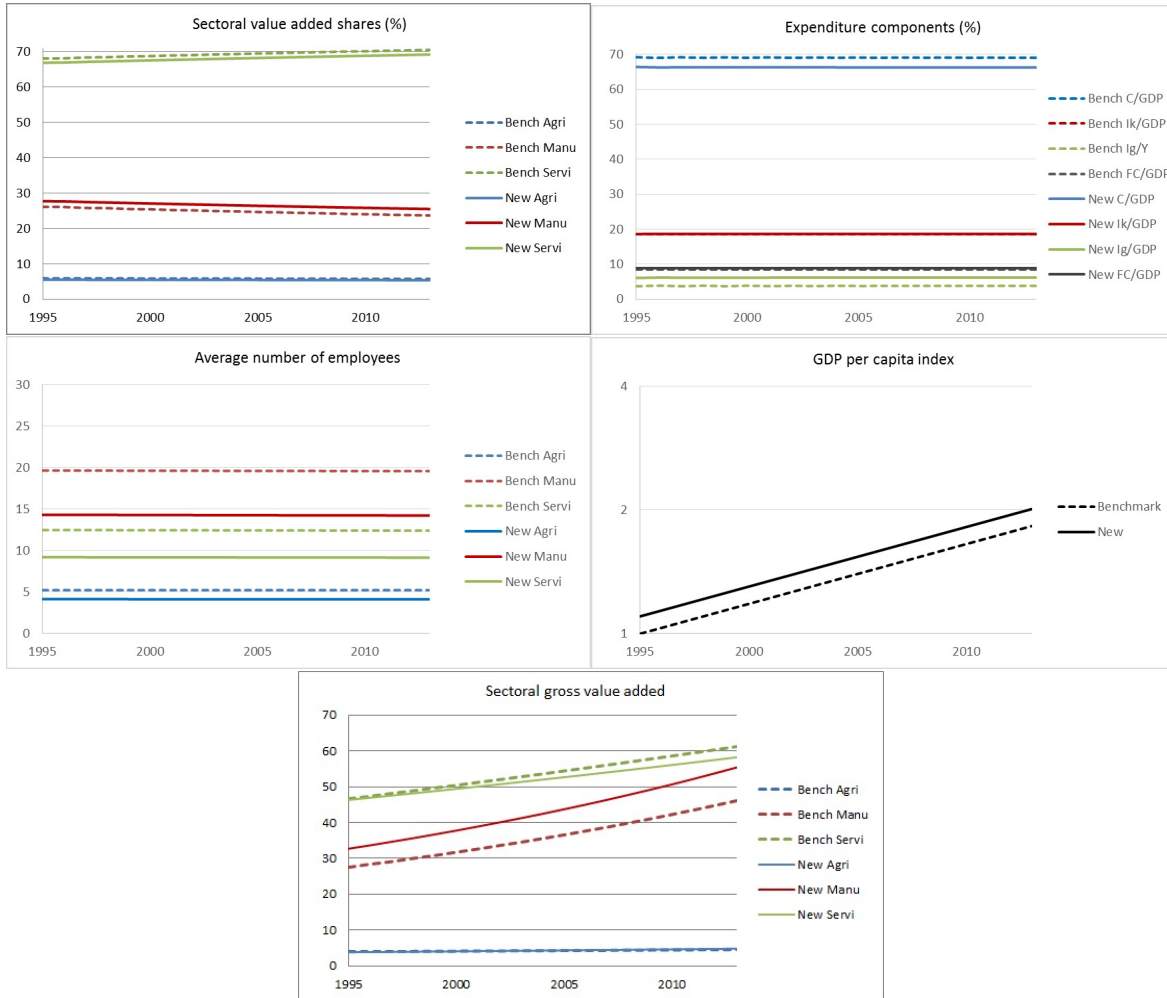
where the actual share declines very little from 1995 to 2013, the public capital growth per se reduces the income share by more than the amount observed in the data. This is why the calibrated rate of TFP growth in the agriculture sector needs to be lower than the one in the manufacturing sector to match the actual numbers. Anyhow, if we combine the necessary changes caused by both the growing G_t and TFP-growth differences, public capital formation explains 59% of the overall variation in the agricultural share. Moving now to the bottom panels, we see that, as directly implied by the calibration, the benchmark predictions reproduce the average number of employees per establishment (left) and average annual growth rate of GDP per capita (right) observed in the Brazilian economy, respectively.

5.2.2   Policy experiments

Our next task is running five policy experiments. The first two consider an acceleration of public capital formation. IBGE data imply that gross public-capital formation has decreased in Brazil from 5.7% of GDP in the 1970s to an average of 3.4% for the period 1985 to 2009. As a consequence, as Calderón and Servén (2010) and Frischtak (2013) among others argue, Brazil's infrastructure investment has fallen in the past few decades below the levels shown by other Latin America and emerging nations such as Chile, China, and India. We now ask our model what would be the impact on the different sectors and the economy as a whole if Brazil had maintained the public-capital formation levels of the 1970s.

We conduct two different experiments to achieve an increase in the ratio of I_{gt} to GDP from 3.4 to 5.7 percent. In the first experiment, this increase comes as the result of stronger incentives to invest in G_t induced by an increase in the political ideology parameter λ. Put differently, the policy maker increases the public capital formation perceived as valuable by her supporting group. For this, we choose $\lambda = 0.64$, which implies that $I_{gt}/GDP = 0.095$, and therefore, the actual public capital formation as per unit of GDP equals $0.095 * 0.60 = 0.057$. All other parameters take on their benchmark numbers.

The results are in Figure 8 and the first column of Table 2. The top right panel depicts the different expenditure categories. Initially, the consumption share is about 69.5%, the one of private investment is around 18.4%, 3.4% for public capital investment, and 8.7% for fixed costs. We can see that the counterpart to the increase of 3.8 percentage points in the public investment share (but 2.3 in terms of public capital formation) is a decline in private consumption. Surprisingly, the fixed cost share goes up, although not by much, namely by 0.33 percentage point. This occurs because of the increase in the number of firms, even though fixed costs per firm have gone up and, as we will see next, firms have become smaller. The other expenditure share, the one for private investment, does not vary.

The middle right panel shows a sizable increase in GDP of 9.55% (see Table 2). Since the stock of G_t almost doubles as a consequence of the increase in ξ, this implies a public

capital elasticity of GDP of about 0.1. In the middle left panel, in turn, we can observe the evolution of the average number of employees: this average clearly declines in all sectors, that is, firms become smaller because fixed costs fall as a consequence of the faster public capital formation. The decrease is larger in manufacturing (5.51 workers), followed by services (3.32 employees) and agriculture (1.14 workers). Looking now at the GVA shares (top left panel), manufacturing is the sector that benefits the most: its share increases by 2.43 percentage points. Even though the services sector also benefits from additional investment, it suffers a decline of 1.94 percentage points in its income share due to the reduction in consumption. Agriculture is less affected by the change in consumption due to its lower weight and declines only by 0.49 percentage point.

The bottom panel in Figure 8 shows the evolution of the real level of production by sector (i.e., the sectoral gross real-value added). It is computed as the GVA share of the sector times GDP divided by the sector's relative price. Manufacturing displays again the largest increase, at 19.79 percent. Agriculture also experiences a gain, although much smaller, at 0.81 percent. The services sector, on the other hand, suffers a decline of 3.14 percent. These results are driven by the same reasons as the changes in the shares explained in the previous paragraph.

The second experiment that achieves an increase in the ratio of I_{gt} to GDP by 5.7% is by decreasing the degree of investment mismanagement in the model economy. In particular, for $\lambda = 0$, we need to increase the value of ξ from 0.60 to 1. Recall that we compare different paths – on this occasion, the benchmark case and the one with $\xi = 1$ – in which the growth rates of GDP, consumption expenditure, and capital stocks are (approximately) constant.

Figure 9 and Table 2 (second column) show the simulation results. We can see in the top left panel that, unlike in our previous experiment, the impact of the increase in ξ on the sectoral income shares is now quantitatively small. The reason is that the share of investment expenditure (i.e., the ratio of I_{gt} to GDP) shows little variation: the decrease in the degree of mismanagement increases incentives for public capital formation, but reduces the needed amount of investment; both effects offset each other almost exactly. Consequently,

Table 2: Differences in predicted values with respect to the benchmark case

Variable	$\lambda = .64$	$\xi = 1$	$\varphi = .1$	$e_m = .4$	$e_i = 1.5, \lambda = -.4$
GVA share of agriculture (%)	-0.49	-0.22	0.00	0.02	0.13
GVA share of manufacturing (%)	2.43	-0.11	0.00	0.25	-1.40
GVA share of services (%)	-1.94	0.33	0.00	-0.27	1.27
Ave. no. of workers in agriculture	-1.14	-1.21	0.00	0.44	1.12
Ave. no. of workers in manufacturing.	-5.51	-5.84	0.00	1.69	5.77
Ave. no. of workers in services	-3.32	-3.52	0.00	0.39	3.44
GDP percentage change	9.55	10.26	0.00	-7.43	-4.79
Agricultural output % change	0.81	6.88	0.00	-5.11	-3.11
Manufacturing output % change	19.79	9.80	0.00	-6.56	-9.99
Services output percentage change	-3.14	0.67	0.00	-10.23	-9.91
Private consumption share (%)	-3.77	-0.32	-6.11	0.00	2.20
Private investment share (%)	-0.00	-0.00	0.00	0.00	0.00
Public investment share (%)	3.80	-0.07	0.00	-0.00	-1.94
Fixed-costs share (%)	0.33	0.39	0.00	-0.00	-0.27

manufacturing and services change little their weights in GDP.

More specifically, the top right panel of Figure 9 says that the expenditure shares do not change much. The largest changes are displayed by consumption and the fixed costs, whose shares go up and down by merely 0.32 and 0.39 percentage points, respectively. Looking now at Table 1, the shares of agriculture and manufacturing fall, on average, by 0.2 and 0.11 percentage points, respectively; whereas one of services increases by 0.33. The logic behind the signs of these changes was explained previously. In particular, the additional capital formation, through differences in the β_is, favors the service sector and diminishes the share of agriculture. The fixed cost channel, to the contrary, due to the decrease in the private-to-public capital ratio, increases the shares of both agriculture and services, especially the one of the former because of its much lower fixed operation cost parameter. In turn, the GVA share in manufacturing decreases through these two channels.

Variables that do vary substantially as a result of the decrease in the degree of misman-agement include the average number of workers per firm (middle left panel), the GDP level (middle right panel), and the levels of sectoral production (bottom panel). The additional capital formation causes an increase in the level of GDP of about 10%, which is almost the

same as what we found in the previous experiment. The average number of employees per establishment also falls significantly: by 1.2 employees in agriculture, 5.8 in manufacturing, and 3.5 in services.

Sectoral shares do not change much in nominal terms; but what about if we abstract from prices and focus exclusively on the output units produced in each sector? The bottom left chart in Figure 9 shows that they increase in all sectors. The variation in services is small, where annual production rises on average only by 0.7%. However, the agriculture and the manufacturing sectors experience a significant increase, 6.7% in the production of the former and 9.8% in the latter. Variation in output prices thus to a large extent offsets the impact of public capital in the real economy. Perhaps more important, the bottom panel also suggests that the size of firms is important to understand the impact of public capital across sectors. Infrastructure formation favors the agriculture sector more than the manufacturing sector due to the larger public capital intensity of the former. However, the manufacturing output in Figure 9 increases in a larger proportion than the agriculture output. The reason is the larger reduction in the size of firms that manufacturing experiences as a consequence of the reduction of the fixed costs. Smaller firms in a model with diminishing returns to private inputs are more efficient in production.

Our next task is looking at how the economy responds to changes in the degree of rent capture. This degree – proxied by the parameter φ – is a source of corruption in our model. However, unlike changes in ξ (the other possible source of corruption), variations in φ are not distortionary of the economy's production capability. Table 2, column 3 shows results when φ rises from zero to 0.1. We see that the increase in rent-capture has no effect on the economy, except for the reduction in private consumption by 6.11 percentage points. Consistent with Shleifer and Vishny's (1993) theoretical model, under centralized corruption politicians realize that optimal government spending maximizes also their rents, and then the economy follows the first-best solution.

Next, we quantify the effect of a decline in the efficiency of government infrastructure in

Figure 9: Comparative dynamics if ξ increases to 1
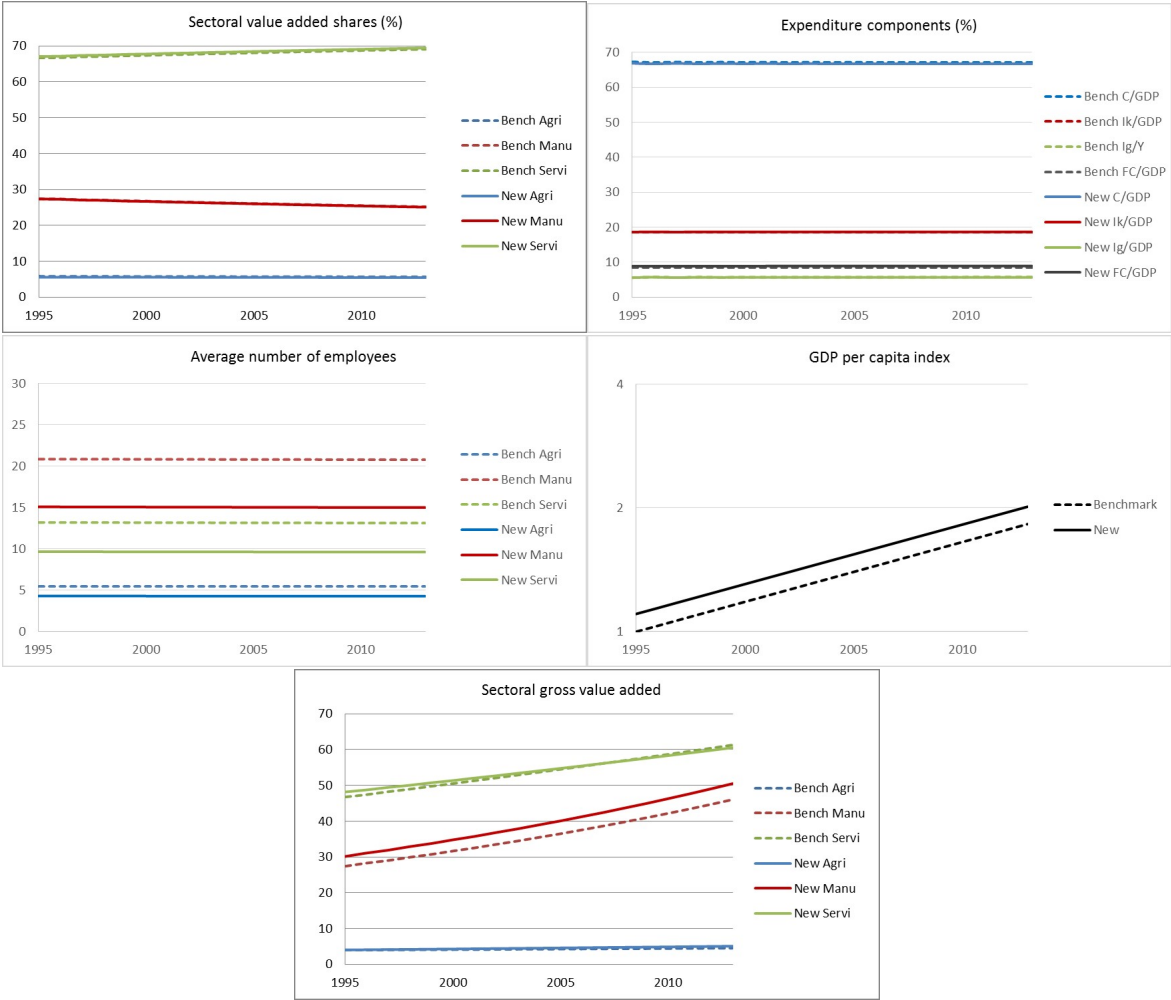
one of the industries, and in particular, a decline of 60% in e_m. Table 2, column 4 displays the simulation results. The GVA shares, the average number of workers and the expenditure shares vary very little. The main consequence of the decline in the relative productivity of private inputs in manufacturing is a significant reduction in the optimal stock of government infrastructure. This reduces GDP by 7.43%, and the units produced in all sectors. As before, due to the reduction in consumption levels, the most affected sector is the services sector that shows an average reduction in its predicted production levels from 1995 to 2013 of 10.2%.

Finally, we try to assess how the subsidization of public capital, a common practice in many developing nations such as India, can affect the industries and the economy. The issue that we face when running this experiment is that public capital services are freely distributed in our model economy. To circumvent this problem, we assume that firms allocate the same amount of resources to pay for public capital regardless of the subsidy received. Concentrating the analyses on the implementation of a 33.3% subsidization rate, this implies that we can capture this policy action assuming that e_i goes up from 1 to 1.5 in all sectors.[22] The bad side of subsidies is that they limit the capacity of the government to invest in public capital. In our case, we suppose that the government collects a 33.3 percent less in revenues, and it also invests less the same amount in infrastructure spending. This is equivalent to decreasing the ratio of the pubic capital formation to GDP until it equals 3.8 percent, which we achieve when λ equals -0.4. In this scenario, in order to keep the public-to-private capital ratio (and then the average number of firms) approximately constant, we need to raise also the parameter β_c to 0.093; all other parameters remain at their benchmark values.

Therefore, we have two opposing forces generated by public capital subsidization. On the one hand, the larger e_i benefits the economy. On the other, a lower investment reduces the available stock of infrastructure, which hurts productivity and increases fixed costs. The results in Column 5 of Table 2 suggest that the negative effect dominates. During the sample period, GDP falls on average a 4.79%, and production levels also decline in all industries,

---

[22]Observe that if 0.667 (1 - 0.333) units of resources provide one unit of G_t, one unit of resources can buy 1.5 units of G_t.

3.11% in the agriculture sector, 9.99% in the manufacturing sector, and 9.91% in the services sector. The increase in the average size of establishments is also substantial in all industries, but especially in manufacturing with 5.77 additional employees. Looking next to the expenditure shares, the ones of consumption and public investment experience a sizable change, 2.20 and -1.94 percentage points, respectively. Finally, the GVA share of manufacturing suffers, declining by 1.40 percentage points, whereas the ones of agriculture and services increase by 0.13 and 1.27, respectively.

6 Conclusion

This paper contributes to the understanding of the structural transformation process by focusing on a previously neglected mechanism (public infrastructure) and by concentrating on the experience of a large developing nation (Brazil). We also contribute by combining elements of the economic growth and heterogeneous firms literatures in our multisector model. In addition, besides the standard role of government infrastructure as an amplifier of the productivity of private inputs, we also consider its capacity to reduce the fixed costs faced by firms.

Using Brazilian data on sectoral GVA shares, expenditure shares of investment, and differences in firm size across industries, our main result confirms that public infrastructure is an important driving mechanism of the structural transformation. More specifically, the accumulation of infrastructure accelerates the process of the structural transformation through effects channeled by cross-sector differences in public capital intensity and entry costs. Quantitatively, the public capital formation can explain about 15% of the process.

We also perform some interesting policy exercises. The first two relate to the Brazilian experience with partisan incentives and problems in regulatory governance that lead to lack of investment and mismanagement of public resources. We find that stronger incentives to invest in the pubic capital have a significant impact on the evolution of the sectoral shares.

In this scenario, the share of manufacturing increases and the ones of the other two production activities decline. On the contrary, a decrease in the degree of mismanagement has negligible effects on the weights of the different sectors in the economy. The reason is that the main driver of the sectoral GVA shares is the distribution of expenditure among the different sectors, regardless of whether or not this expenditure is mismanaged. Importantly, improvements in both the incentives to carry out infrastructure investment and public management have a significant positive effect on total GDP and production levels, especially in the manufacturing sector.

The third policy experiment analyzes the consequences of variations in the rent-seeking behavior of politicians that targets consumption units. We find no effect on the economy because politicians have incentives to pursue the first-best. Finally, we show that public-services subsidization practices of the type followed by nations like India, which limit the capacity of the government to invest in infrastructure formation, can have a significant negative effect on GDP per capita and the share of the manufacturing sector in the economy.

References

[1] Acemoglu, Daron, and Veronica Guerrieri. Capital Deepening and Non-Balanced Economic Growth. Journal of Political Economy 116: 467-498, 2008.

[2] Agénor, Pierre R. A theory of Infrastructure-Led Development. Journal of Economic Dynamics and Control, 34(5): 932-950, 2010.

[3] Agénor, Pierre R. Public Capital, Growth and Welfare. Princeton University Press, Princeton, New Jersey, 2012.

[4] Alfaro, Laura, Andrew Charlton, and Fabio Kanczuk. Plant-Size Distribution and Cross-Country Income Differences. In NBER International Seminar on Macroeconomics 2008, ed. Jerey A. Frankel and Christopher Pissarides, (National Bureau of Economic Research, 2009).

[5] Alonso-Carrera, Jaime, Maria Jesus Freire-Seren, and Xavier Raurich. Anatomizing the Mechanics of Structural Change. Mimeo, University de Barcelona.

[6] Alvarez-Cuadrado, Francisco, Ngo Van Long and Markus Poschke. Capital-Labor Substitution, Structural Change and Growth. Manuscript, 2016. Forthcoming in Theoretical Economics,

[7] Amann, Edmund, Werner Baer, Thomas Trebat and Juan Villa Lora. Infrastructure and its Role in Brazil's Development Process. *Quarterly Review of Economics and Finance* 62: 66-73, 2016.

[8] Aschauer, David Alan. Does Public Capital Crowd Out Private Capital? Journal of Monetary Economics 24(2): 171-188, 1989.

[9] Bar, Michael, and Oksana Leukhina. Demographic Transition and Industrial Revolution: A Macroeconomic Investigation. Review of Economic Dynamics 13: 424-451, 2010.

[10] Barro, Robert. Government Spending in a Simple Model of Endogeneous Growth. Journal of Political Economy 98(5): S103-S125, 1990.

[11] Baumol, Willliam. Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis. American Economic Review 57: 415-426, 1967.

[12] Bento, Pedro, and Diego Restuccia. Misallocation, Establishment Size, and Productivity. NBER Working Paper No. 22809, 2016. Forthcoming in American Economic Journal: Macroeconomics.

[13] Betts, Caroline, Rahul Giri and Rubina Verma. Trade, Reform, and Structural Transformation in South Korea. IMF Economic Review, https://doi.org/10.1057/s41308-017-0031-7, 2017

[14] Bollard, Alpert, Peter J. Klenow and Huiyu Li. Entry Costs Rise with Development. Manuscript, Stanford University, 2016.

[15] Buera, Francisco J., and Joseph P. Kaboski. Can Traditional Theories of Structural Change Fit the Data? Journal of the European Economic Association 7: 469-477, 2009.

[16] Buettner, Thiess, and Fédéric Holm-Hadulla. City Size and the Demand for Local Public Goods. Regional Science and Urban Economics 43: 16-21, 2013.

[17] Calderón, Cesar, and Luis Servén. Infrastructure in Latin America. World Bank Policy Research Working Paper No. 5317 (Washington: World Bank), 2010.

[18] Caselli, Francesco, and Wilbur J. Coleman. The U.S. Structural Transformation and Regional Convergence: A Reinterpretation. Journal of Political Economy 109: 584-616, 2001.

[19] Chakraborty, Shankha, and Amartya Lahiri. Costly Intermediation and the Poverty of Nations. International Economic Review 48(1): 155-183, 2007.

[20] Cubas, German. Lack of Infrastructure? Public Capital and Economic Development. Mimeo, University of Houston.

[21] Dabla-Norris, Era, Jim Brumby, Annette Kyobe and Zac Mills and Chris Papageorgiou. Investing in Public Investment: An Index of Public Investment Management Efficiency. Journal of Economic Growth 17(3): 235-266, September 2012.

[22] Echevarria, Cristina. Changes in Sectoral Composition Associated with Economic Growth. International Economic Review 38: 431-452, 1997.

[23] Felice, Giulia. Size and Composition of Public Investment, Sectoral Composition and Growth. European Journal of Political Economy 44: 136-158, 2016.

[24] Fernald, John G. Roads to Prosperity? Assessing the Link between Public Capital and Productivity. The American Economic Review 89(3): 619-638, 1999.

[25] FIESP. Relatório Corrupção: Custos Econômicos e Propostas de Combatea. Federation of Industries of Sao Paulo State, DECOMTEC, March 2010.

[26] Foster, Vivien, and Jevgenijs Steinbuks. Paying the Price for Unreliable Power Supplies: In-House Generation of Electricity by Firms in Africa. World Bank Policy Research Working Paper 4913, 2009.

[27] Frischtak, Cláudio R. Infraestructura e desenvolvimento no Brasil. In Desenvolvimento Econômico: Uma Perspectiva Brasileira, Fernando Veloso (Eds), Elsevier, Rio de Janeiro, 322-347, 2013.

[28] Glomm, Gerhard, and B. Ravikumar. Public Investment in Infrastructure in a Simple Growth Model. Journal of Economic Dynamics and Control, 18(6): 1173-1187, 1994.

[29] Gollin, Douglas, Remi Jedwab and Dietrich Vollrath. Urbanization With and Without Industrialization. Journal of Economic Growth 21(1): 35-70, 2016.

[30] Gollin, Douglas, Stephen Parente and Richard Rogerson. The Role of Agriculture in Development. American Economic Review 92: 160-164, 2002.

[31] Guillo, Maria D., Chris Papageorgiou and Fidel Perez-Sebastian. A Unified Theory of Structural Change. Journal of Economic Dynamics and Control 35: 1393-1404, 2011.

[32] Herrendorf, Berthold, Christopher Herrington and Ákos Valentinyi. Sectoral Technology and Structural Transformation. American Economic Journal: Macroeconomics 7(4): 104–133, 2015.

[33] Herrendorf, Berthold, Richard Rogerson and Akos Valentinyi. Two Perspectives on Preferences and Structural Transformation. American Economic Review 103, 2013.

[34] Herrendorf, Berthold, Richard Rogerson and Akos Valentinyi. Structural Transformation and Economic Growth. In: Aghion, Philippe, Durlauf, Steven (Eds.), Handbook of Economic Growth, vol. 2B. North Holland, Amsterdam and New York, 855-941, 2014.

[35] Herrendorf, Berthold, James A. Schmitz and Arilton Teixeira. The Role of Transportation in U.S. Economic Development: 1840-1860. International Economic Review 53(3): 693-715, 2012.

[36] Kamps, Christophe. New Estimates of Government Net Capital Stocks for 22 OECD Countries, 1960-2001. IMF Staff Papers 53, 120-150, 2006.

[37] Karadiy, Peter, and Miklos Korenz. Cattle, Steaks and Restaurants: Development Accounting when Space Matters. Mimeo, Central European University, 2017.

[38] Kessides, Christine. A Review of Infrastructure's Impact on Economic Development. In: Batten, David F. and Karlsson, Charlie (Eds.), Infrastructure and the Complexity of Economic Development, Springer, Berlin, Heidelberg, 213-230, 1996.

[39] Kongsamut, Piyabha, Sergio Rebelo and Danyang Xie. Beyond Balanced Growth. Review of Economic Studies 68: 869-882, 2001.

[40] Laincz, Christopher A., and Pietro F. Peretto. Scale Effects in Endogenous Growth Theory: An Error of Aggregation Not Specification. Journal of Economic Growth 11(3): 263-288, 2006.

[41] Laitner, John. Structural Change and Economic Growth. Review of Economic Studies 67: 545- 561, 2000.

[42] Lee, Sik Kyu, and Alex Anas. Costs of Deficient Infrastructure: The Case of Nigerian Manufacturing. Urban Studies 29(7): 1071-1092, 1992.

[43] Leukhina, Oksana M., and Stephen Turnovsky. Push, Pull, and Population Size Effects in Structural Development: Long-run Tradeoffs. Journal of Demographic Economics 82(4): 423-457, 2016.

[44] Melo, Patricia C., Daniel J. Graham and Ruben Brage-Ardao. The Productivity of Transport Infrastructure Investment: A Meta-Analysis of Empirical Evidence. Regional Science and Urban Economics 43(5): 695-706, September 2013.

[45] Matsuyama, Kiminori. Agricultural Productivity, Comparative Advantage, and Economic Growth. Journal of Economic Theory 58: 317-334, 1992.

[46] Nagy, David K. City Location and Economic Development. Mimeo, CREI, Universitat Pompeu Fabra, 2017.

[47] Ngai, L.R., and C.A. Pissarides. Structural Change in a Multi-Sector Model of Growth. American Economic Review 97: 429-443, 2007.

[48] Ojo, Funmi, and Allison Everhardt. Brazilian Infrastructure and Corruption. In America's Business Intelligence,Washington, D.C., October 11, 2013.

[49] Porter, Michael E. Location, Competition, and Economic Development: Local Clusters in a Global Economy. Economic Development Quarterly 14(1): 15-34, 2000.

[50] Poschke, Markus. The Firm Size Distribution Across Countries and Skill-Biased Change in Entrepreneurial Technology. Manuscript, McGill University, 2017.

[51] Reinikka, Ritva, and Jakob Svensson. Coping with Poor Public Capital. Journal of Development Economics 69(1): 51-69, 2002.

[52] Restuccia, Diego, and Richard Rogerson. Policy Distortions and Aggregate Productivity with Heterogeneous Establishments. Review of Economic Dynamics 11: 707-720, 2008.

[53] Rioja, Felix K. Growth, Welfare, and Public Infrastructure: A general Equilibrium Analysis of Latin American Economies. Journal of Economic Development, 26(2): 119-130, 2001.

[54] Shleifer, Andrei, and Vishny, Robert W. Corruption. The Quarterly Journal of Economics, 108(3): 599-617, 1993.

[55] Steinbuks, Jevgenijs, and Vivien Foster. When do firms generate? Evidence on in-house electricity supply in Africa. Energy Economics 32(3): 505-514, 2010.

[56] Steinbuks, Jevgenijs. Firms' Investment under Financial and Infrastructure Constraints: Evidence from In-House Generation in Sub-Saharan Africa. The BE Journal of Economic Analysis & Policy 12,(1), 2012.

[57] Tabellini, Guido, and Alberto Alesina. Voting on the Budget Deficit. American Economic Review, 80: 37-49, 1990.

[58] Teignier, Marc. The Role of Trade in Structural Transformation. Manuscript, University of Barcelona, 2016. Forthcoming in Journal of Development Economics.

[59] Uy, Timothy, Kei-Mu Yi and Jing Zhang. Structural Change in an Open Economy. Journal of Monetary Economics 60(6): 667-682, 2013.

[60] World Bank. How to Decrease Freight Logistics Costs in Brazil. Washington: World Bank, 2012.

A Variables and parameters of the model

Endogenous variables	Exogenous variables and parameters
c_{it}: consumption of sector i products	A_{it}: technology level in sector i
c_t: consumption bundle	q: firm's productivity
w_t: wage rate	e_{it}: quality of public infrastrucutre in sector i
r_t: interst rate	ω_i: weight of sector i in consumption
b_t: consumer's stock of bonds	μ: weight of public services in consumption
τ_t: lump sum taxes per capita	ε: elasticity of consumption
p_{it}: price of sector-i products	δ_k: depreciation rate of phisical capital
P_{ct}: consumption price incex	δ_g: deprecitation rate of infrastructure
l_{it}: labor employed in sector i	α: share of capital in production
k_{it}: capital employed by sector i	β_i: infrastructure share in sector-i production
K_t: economy's capital stock	γ: share of labor in production
y_{it}: firm's prodcution in sector i	β_c: elasticity of public capital in preferences
Y_{it}: total production in sector i	f_q: entry cost parameter
F_{qt}: fixed cost of entry	f_{oi}: operation cost parameter in sector i
F_{oit}: fixed cost of operation in sector i	ψ: total fixed cost elasticity
$\hat{q}_{it}$: productivity threshold in sector i	θ: fixed-costs elasticity of K-G ratio
π_{it}: firm's profits in sector i	φ: weight of rents in welfare function
d_t: dividents per consumer	ρ: subjective discount factor
I_{kt}: investment in physical capital	ξ: mismanagement parameter
I_{gt}: investment in public infrastructure	λ: policymaker's ideology parameter
G_t: stock of public infrastructure	
R_t: rents captured by polititians	
N_{it}: number of firms in sector i	
Z_{xt}: steady-state growth rate of variable x	

B GVA sectoral shares in Brazil, 1985-1995

Figure 10: Sectoral shares of Brazilian GVA (left panel) and firms (right panel)