Public Infrastructure and Structural Transformation*

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Preliminary and incomplete

Abstract

This study argues that public infrastructure is an important though previously neglected driving mechanism of the structural transformation. To quantitatively assess its significance we first develop a multisector neoclassical growth model with heterogeneous firms, where public infrastructure contributes to firms’ production and mitigates the barriers to firms’ entry. We then calibrate the model using data of Brazil, a country that have significantly expanded its infrastructure in recent decades yet remains in deep need for further infrastructure improvements. Accumulation of infrastructure accelerates the process of the structural transformation through effects channeled by cross-sector differences in public capital intensity and entry costs. Nevertheless, other factors such as public sector mismanagement and higher technological progress in sectors with low public capital intensity reduce the strength of the structural transformation effects of infrastructure.

Keywords: Brazil, infrastructure, structural transformation

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1 Introduction

The process of the structural transformation, that is, the reallocation of inputs to more productive activities is recognized as an important feature of successful economic development. Focusing on the three largest economy sectors, this process is characterized by a reallocation of productive resources from agriculture to manufacturing and services, and later from agriculture and manufacturing into services.\footnote{We adopt the definition of the three sectors supplied by Herrendorf et al. (2014) in their survey of the literature. In particular, agriculture includes cultivation and breeding of animals, plants and fungi. Manufacturing captures all activity that falls outside of agriculture and services. Finally, the category services refers to the tertiary sector.} In the last few years, another aspect that is acquiring a prominent place in the economic policy agenda is public infrastructure formation. The reason is that public capital is perceived as a key complementary factor to private inputs. Necessary infrastructure includes, for instance, roads, airports, electricity networks, and institutions that favor production over diversion. Nevertheless, our understanding of how these two important processes interact is limited. The goal of this paper is two-fold. First, it wants to assess the importance of public infrastructure formation in the structural transformation, and vice versa. Second, we want to understand how different constraints to public capital accumulation impact infrastructure and the structural transformation.

As a first approximation to the possible relationship between the two, we can easily observe for example that they are correlated. Figure 1 shows two different panels with cross-sectional data provided by the World Bank for 263 nations along with trend lines. The left panel of Figure 1 plots the income share of agriculture against the number of monthly power outages, averaged for the period 2016-2015. We observe that economies that depend more heavily on agriculture suffer, 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 monthly power outages for the above time interval and same sample of countries. This time electricity infrastructure improves with the share of manufacturing in GDP, reducing the average number of outages. Interestingly, the hump-shaped relationship between GDP...
Figure 1: Income shares of agriculture (left chart) and manufacturing (right chart) versus average power outages per month:

2006-15, 263 nations (source: World Bank, Enterprise Surveys (http://www.enterprisesurveys.org/))

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 trend-lines (linear and quadratic) are always strictly decreasing. This suggests that the correlation between the two might not be just a consequence of richer economies providing better infrastructure, and that therefore it deserves further research.

To achieve our goal, we built a multisectoral general equilibrium model of unbalanced economic growth that is later analyzed quantitatively. In this framework, the three sectors — agriculture, manufacturing and services — coexist within a closed economy, except for the capital market that is open. They enjoy 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 non-rival and increases the productivity of private inputs. In turn, establishments have plant-specific productivity and are free to enter and exit markets. We consider firm heterogeneity because, besides the standard complementarity between public and private capital considered in the literature, public infrastructure in our model also helps reducing fixed costs of operation. That is, the lack of sufficient public capital acts as a barrier to the

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2 The unbalanced growth feature of the model should not be perceived as a caveat. As Herendorf 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.”
entry of firms into markets. This feature is motivated, for example, by the observation that fixed costs such as legal fees, brides, security and some indivisible equipment depend on the quality of regulatory governance and public utility networks. The size of the fixed costs will also contribute to endogenously determine the average productivity level in each industry and affect input reallocation across sectors.

The quantitative analysis takes the Brazilian data as its reference. We choose this country because Brazil is widely considered to be in deep need of further infrastructure investment. Looking for example at the Global Competitiveness Report 2016-17, Brazil’s quality of overall infrastructure stands at 116th place out of 138 nations. 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 that goes from 1995 to 2013. During that time, the value added shares of agriculture and manufacturing have declined, and the one of services increased. As expected, these patterns are replicated by the sectoral employment shares. Regarding firm sizes, manufacturing have, on average, the largest firms, followed by services, and agriculture that have the smallest ones. The average establishment size seems to have declined in all sectors from 1995 to 2013.3

Our results indicate that the accumulation of infrastructure contributes to speed up the process of the structural transformation. More specifically, when sectors are complementary, their income share increases with the relative product price. Because services are the least intensive in public capital, 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 looks the most intensive in government-provided capital. At the same time, the increasing importance of the least intensive sector—that is, services—reduces the incentives for public capital formation.

3The 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 Laínez and Peretto (2006) report no trend in average firm employment in the U.S. More recent papers, on the contrary, like Poschke (2017) and Bento and Restuccia (2017) document that average establishment size is positively correlated with GDP per capita in the cross-section of countries.
On the other hand, the effects that run through the fixed costs can have, by construction, only level effects and do not affect the speed of the structural transformation. Interestingly, the impact goes in the other direction, because output prices in the model increase with the relative fixed cost that the industry faces. Therefore, since fixed costs decline with public capital, additional infrastructure formation induces a smaller share of the industry. Taking the size of the average firm as an indication of the fixed costs face, manufacturing that have the largest average firms will have higher fixed costs. As a result, public capital will push the value added share of this sector up; whereas by the same token it will tend to decrease the share of agriculture, which is the one with the smallest firms in the Brazilian data.

Quantitative results. TBC.

The literature on the structural transformation, surveyed for example by Herrendorf et al. (2014), is extensive. Within it, two main driving mechanisms stand out. The first one is based on consumers' non-homothetic preferences, pioneered by Konsamut, Rebello and Xie (2001). 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 structural change. The second one is offered by Baumol (1967) and more recently Ngai and Pissarides (2007). Ngai and Pissarides (2007) develop a framework that builds on sector-biased technical change. Ngai and Pissarides show that if there are two industries, one characterized by a larger total factor productivity (TFP) growth, hours of work rise in the stagnant activity if the two goods have a relatively large degree of complementarity; otherwise labor moves in the direction of the progressive sector.

An alternative mechanism is proposed by Caselli and Coleman (2001), who consider that non-agriculture is more skill intensive than agriculture. Acemoglu and Guerrieri (2008) offer an explanation of the structural transformation based on capital accumulation and

\[ \text{Quantity side channels are presented in Matsuyama (1992), Echevarria (1997), Laitner (2000), and Gollin et al. (2002), among others.}\]

\[ \text{Buera and Kaboski (2009) and Guiollo et al. (2011) also provide support in favor of biased technical change.}\]
sectoral capital-intensity differences. Bar and Leukhina (2010) and Leukhina and Turnovsky (2016), in turn, investigate the effects of population size increases. Alvarez-Cuadrado et al. (2016) have pointed out that relative sectoral output prices depend also on the elasticity of substitution between capital and labor. Finally, the impact of openness to international trade on the structural transformation is studied by Uy et al. (2013) and Tegnier (2016), among others. None of them focus on the role of public capital.

Our paper is also related to the literature on the effects of public infrastructure. TBC.

The rest of the paper is organized as follows. The model is presented in the next section. Section 3 studies a particular case that delivers a balanced-growth path, although without structural transformation. The Brazilian experience is described in section 4. The quantitative analysis and results of the paper are presented in section 5. Section 6 concludes.

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 free international movement of capital. All other markets are closed. Within all production activities, there is free entry and exit of heterogeneous firms. Establishments 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. 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. It is provided by rent-seeking politicians and financed through lump-sum consumer taxes. The model variables and parameters are described in the technical appendix.
2.1 Households

The economy is composed of infinitely-lived individuals that show preferences defined over 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.

The problem faced by a representative consumer is the following:

\[
\begin{align*}
& \max_{\{c_t,b_{t+1}\}} \left\{ \sum_{t=0}^{\infty} \rho^t \ln(c_t) \right\} \\
\text{subject to} & \\
& w_t + d_t + b_t(1 + r_t - \delta_k) - \tau_t = p_{at}c_{at} + c_{mt} + p_{st}c_{st} + b_{t+1},
\end{align*}
\]

where

\[
\begin{align*}
c_t &= \left[ \frac{1}{\omega_a} c_{at}^{\frac{\varepsilon-1}{\varepsilon}} + \frac{1}{\omega_m} c_{mt}^{\frac{\varepsilon-1}{\varepsilon}} + \left(1 - \omega_a - \omega_m\right) \frac{1}{\varepsilon} c_{st}^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}.
\end{align*}
\]

In the above problem, the parameter \(\varepsilon \in (0, \infty)\) represents the elasticity of substitution between goods in consumption, \(\eta > 0\) is a scaling factor, the coefficient \(\omega_i\) represents the weight of sector \(i\) in the consumption bundle \(c_t\), and \(\rho\) is the subjective discount factor. 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 \(\delta_k\). Each individual pays lump-sum taxes \(\tau_t\) to the government.

The solution to this problem results in the following optimality conditions for consumption:

\[
\frac{P_{c,t+1}c_{t+1}}{P_c c_t} = \rho (1 + r_{t+1} - \delta_k),
\]
\[(p_{it}c_{it}) \left( \frac{p_{it}}{P_{ct}} \right)^{1-\varepsilon}; \]

where the exact CES price of the consumption bundle equals

\[P_{ct} = \left( \sum_{i=a,m,s} \omega_{i}p_{it}^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}.\]

Equalities (4) and (5) represent the intertemporal and the inter-sector 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 \(\omega_{i}\) 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 relatively substitutes, \(\varepsilon > 1\); finally, if \(\varepsilon\) equals one, the share is constant and equal to its 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. These 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, and represents a non-rival good whose stock is used simultaneously by all firms. Total factor productivity depends on a sector specific parameter \(A_{i}\) that grows at the exogenous gross rate \(Z_{A_{i}}\) and a firm-specific efficiency coefficient \(q\). As in Baumol (1967), and more recently Ngai and Pissarides (2007), sector-biased technical
change – that is, differences in the growth rate of $A_i$ across sectors– will be the 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:

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

where $\beta_i$ 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 appropriateness 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 productivity. These first order conditions are given by:

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

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

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:

$$\frac{k_{it}(q)}{l_{it}(q)} = \frac{\alpha w_t}{\gamma r_t}, \quad (10)$$
\begin{align*}
l_{it}(q) &= \left[ p_{it}A_{it}q \left( e_{it}G_{it} \right)^{\beta_i} \left( \frac{\gamma}{w_t} \right)^{1-\alpha} \left( \frac{\alpha}{r_t} \right)^{\alpha} \right]^{\frac{1}{1-\alpha-\gamma}}, \\
k_{it}(q) &= \left[ p_{it}A_{it}q \left( e_{it}G_{it} \right)^{\beta_i} \left( \frac{\alpha}{r_t} \right)^{1-\gamma} \right]^{\frac{1}{1-\alpha-\gamma}},
\end{align*}

and

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

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 \( t \).

Firms build their stocks of physical capital borrowing saving to buy units from manufacturing and services that are combined according to the following CES technology:

\[ x_t = \left[ \mu_{m,t}^{\frac{1}{\nu}} + (1-\mu_{m,t})^{\frac{1}{\nu}} x_{st} \right]^{\frac{1}{\nu-1}}; \]

where \( x_t \) represents investment at date \( t \); \( x_{it} \) is the amount of sector-\( i \) products employed in capital formation; \( \nu \) is the elasticity of substitution among investment products; and \( \mu_i \in (0,1) \). This technology is based on the observation that over time, due to for instance the increasing importance of software, the service sector has increase very significantly its contribution to total investment. A consequence of this phenomenon is that, since year 2000, total investment in the US exceeds the size of the whole manufacturing sector. It is straightforward to derive that the optimal demand of investment goods obey the following condition:

\[ \frac{p_{it}x_{it}}{P_{xt}x_t} = \mu_i \left( \frac{p_{it}}{P_{xt}} \right)^{1-\nu}; \]

where the price of the investment bundle equals

\[ P_{xt} = \left( \sum_{i=m,s} \mu_i p_{it}^{1-\nu} \right)^{\frac{1}{1-\nu}}. \]

As in the case of the consumption bundle, if the two investment goods are complementary
(i.e., $\nu \in (0, 1)$), the investment share of sector $i$ goes up with its relative price; the opposite occurs when investment goods are substitutes (i.e., $\nu > 1$); if $\nu = 1$ then the shares are constant.

Establishments are heterogeneous due to the plant-level productivity parameter $q$. The firm’s type is a realization of $q$ drawn from a log-normal distribution with mean $\mu$, standard deviation $\sigma$ and density function $h(q)$; draws are i.i.d. across entrants. In order to know $q$ 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,

$$F_{qt} = f_q A_{mt}^\psi,$$  \hspace{1cm} (17)

$$F_{oit} = f_{oi} A_{mt}^\psi \left( \frac{K_t}{G_t} \right)^\theta;$$  \hspace{1cm} (18)

where the parameters $\theta, \psi > 0$; and $K_t$ is the total stock of capital in the economy at $t$. Variables $F_{qt}$ and $F_{oit}$ are expressed in units of manufacturing output. In addition, $F_{qt}$ implicitly incorporates a premium to cover it for those firms that decide to enter but that eventually, due to a bad draw of $q$, can not pay it fully after production occurs.

Expressions (17) and (18) say that the 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 evidence presented by Bollard et al. (2014), among others. Examples of $F_{qt}$ include licenses, permits and registration fees needed to start a business. Examples of $F_{oit}$ include any barrier to operation that imposes a cost that rises with the ratio of private to public capital. These costs can be direct, like bribes, lawyers or private security intended to prevent expropriation, or indirect, for example due to power outages 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.\textsuperscript{6}

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:

$$\int_{0}^{\infty} [\pi_{it}(q) - F_{oit}] h(q) dq - F_{qt} = 0; \quad (19)$$

In addition, after they know the type, firms will operate in a given period provided that they can obtain positive profits, that is, if $q \geq \hat{q}_{it}$, where

$$\pi_{it}(\hat{q}_{it}) - F_{oit} = 0. \quad (20)$$

From free entry conditions (19), we can write output prices as

$$p_{it} = \frac{A_{mt} (e_{mt} G_t)^{\beta_m}}{A_{it} (e_{it} G_t)^{\beta_i}} \left[ \frac{f_q + f_{oa} \left( \frac{K_i}{G_t} \right)^{\theta}}{f_q + f_{om} \left( \frac{K_i}{G_t} \right)^{\theta}} \right]^{1-\alpha-\gamma}. \quad (21)$$

Unlike in more standard multisector models with Cobb-Douglas production functions in which 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.

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

\textsuperscript{6}Papers in the literature, such as Restuccia and Rogerson (2008), usually assume in their formulation of the model that the entry cost $F_{qt}$ is only paid in the period of entry. 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. This is reinforced, for example, by the fact that Restuccia and Rogerson (2008) assume that the entry cost is zero in the simulations.
the efficiency parameter $q$ as follows:

$$\frac{l_{it}(q)}{l_{it}(q')} = \frac{q}{q'}, \text{ for } i = a, m, s. \quad (22)$$

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

$$\frac{l_{it}(q)}{l_{mt}(q)} = \left[ f_q + f_{oi} \left( \frac{K_t}{C_t} \right) \theta \right]^{1-\alpha-\gamma} \left[ f_q + f_{om} \left( \frac{K_t}{C_t} \right) \theta \right]^{1-\alpha-\gamma}, \quad (23)$$

for $i = a, s$. That is, across industries, the hired amount of labor exclusively varies due to 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 (19) and (20) combining the free entry condition in manufacturing and the operation conditions. We obtain to denote

$$\hat{q}_{it} = \begin{cases} E \left[ q^{\frac{1}{1-\alpha-\gamma}} \right]^{1-\alpha-\gamma} \\ 1 + \frac{f_q}{f_{oi} \left( \frac{K_t}{C_t} \right) \theta} \end{cases} \quad (24)$$

The expected value of $q^{\frac{1}{1-\alpha-\gamma}} \left( E[q^{\frac{1}{1-\alpha-\gamma}}] = \int_0^\infty q^{\frac{1}{1-\alpha-\gamma}} h(q) \, dq \right)$ and the fixed costs are its main determinants. To understand this, notice 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 rises the size of the average firm. A larger sector-specific costs of operation, on the other hand, demands a larger size.

Finally, the amount of profits that firms are able to obtain can be written as a function of the fixed costs and the plant productivity index, because the last two variables determine
the firm’s size. More specifically, equalities (13) to (19) and (24) obtain

\[ \pi_{it}(q) = (1 - \alpha - \gamma) \left( \frac{q}{q_{it}} \right)^{\frac{1}{1-\alpha-\gamma}} F_{ot}. \]  

(25)

Implicitly, expression (25) 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. Therefore, in order to cover as well the entry costs \( F_{ot} \) and obtain strictly positive net profits, this ratio needs to be sufficiently larger than one.

### 2.3 The government

We assume that the public sector is an infinitely-lived institution composed of rent-seeking politicians and potentially affected by mismanagement. Their problem is choosing the amounts of rent capture \( (R_t) \) and public infrastructure to maximize a welfare function that weighs the present value of consumer’s utility and \( R_t \). 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.

Because we assume that the government combines manufacturing and service products to build infrastructure in the same manner as the private sector using technology (14), it is then immediate that its demand for investment goods will also obey function (15).

Therefore, we can concentrate on the following problem:

\[
\max_{\{R_t, G_{t+1}\}} \left\{ \varphi \ln(R_t) + \sum_{t=0}^{\infty} \rho^t \ln(c_t) \right\};
\]

(26)

where \( \rho \in (0, 1) \) is the time-preference coefficient; \( \varphi \geq 0 \). A way to justify that only current rents extraction is valued in expression (26) is assuming that politicians stay in office for one period; alternatively, we can think that politicians believe that their corrupt behavior might not be sustainable in the near future.
Objective function (26) is maximized subject to the economy’s feasibility condition:

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

(27)

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

\[ Y_{it} = N_{it} \int_{q_{it}}^{\infty} y_{it}(q) h(q) \, dq. \]  

(28)

Notice that the sum of \( I_{gt} \) and \( I_{kt} \) must be equal to the available amount of investment \( x_t \) given by expression (14). Equality (27) says that total production (i.e., GDP) is allocated to finance the fixed costs, consumption, investment, and rent capture. Notice that this expression also represents the government’s budget constraint, because it implies that the amount paid by consumers as taxes \( \tau_t \)—production minus fixed costs minus private investment minus consumption— is allocated between public capital formation and rent extraction.

Following Darla-Norris et al. (2002), we consider that the government suffers from mismanagement of public investment. In particular, a \( I_{gt} \) equal one unit delivers \( \xi < 1 \) units of public-capital value (e.g., due to corruption or indolence). As a result, investment \( I_{gt} \) serves the maintenance and construction of infrastructure according to the following motion equation:

\[ G_{t+1} = (1 - \delta_g) G_t + \xi I_{gt}; \]  

(29)

where the parameter \( \delta_g \) represents the depreciation rate of government infrastructure.

The first order condition to the government’s problem—given by expressions (26) to (29)—with respect to \( R_t \) predict that rents are a fraction \( \varphi \) of total aggregate consumption:

\[ R_t = \varphi L_t P_{ct} c_t. \]  

(30)
Whereas the one with respect to $G_{t+1}$ provides the intertemporal condition:

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

(31)

It gives the optimal evolution of total consumption expenditure from the government’s viewpoint. Unlike in expression (4), where the consumer links intertemporal consumption to the return to saving, the policymaker in (31) relates consumption expenditure growth to the marginal return to public capital investment. A return that takes into account that a higher $G_{t+1}$ will increase private input productivity and reduce firms’ fixed costs, but that not the whole amount of public investment translate into public capital due to mismanagement.

Putting together (4) and (31), employing as well (7), (8), (28), (9), (19) and (20), obtains

$$
\frac{1 + r_t - \delta_k}{\xi} = 1 - \delta_g + \sum_{i=a,m,s} N_{it} \left\{ \beta_i \frac{\int_{\hat{q}} \hat{q}^{\frac{1}{1-\alpha-\gamma}} h(q) \left( F_{qt} + F_{oit} \right)}{(1 - \alpha - \gamma) E \left[ q^{\frac{1}{1-\alpha-\gamma}} \right]} + \theta \frac{F_{oit}}{G_{t}} \right\}.
$$

(32)

It is equivalent to 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. In expression (32), it is evident again that the stock of infrastructure $G_t$ affects the productivity of all firms in the economy, regardless of their sector, due to its non-rival nature. Thus meaning that the productivity of infrastructure is larger than the one perceived by the individual firm. It is also clear that a larger degree of mismanagement of public funds (a lower $\xi$) leads to a decrease in public capital formation.

### 2.4 Market clearing

To wrap up 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 expression (8). Hence, labor market clearing requires:

\[
\sum_{i=a,m,s} p_{it} A_{it} (e_{it} G_{it})^\beta_i \left( \frac{\gamma}{w_t} \right)^{1-\alpha} \left( \frac{\alpha}{r_t} \right)^\alpha \frac{1}{1-\alpha-\gamma} N_{it} \int_{\hat{q}_{it}}^{\infty} q^{\frac{1}{1-\alpha-\gamma}} h(q) dq = 1; \quad (33)
\]

Let us now turn to the funds market. The amount of domestic saving available in the economy equals \( b_{t+1} - b_t \). However, capital markets are open, and then the supply of saving can be considered actually 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. Expression (9), on the other hand, determines the per-firm demand of capital in the different sectors, which implicitly pins down investment in private capital formation, \( I_{kt} \). Starting from the motion equation of private capital, we can then write

\[
K_{t+1} = (1 - \delta_k)K_t + I_{kt}. \quad (34)
\]

Which can be further disaggregated in

\[
K_t = \sum_{i=a,m,s} \left[ p_{it} A_{it} (e_{it} G_{it})^\beta_i \left( \frac{\gamma}{w_t} \right)^{1-\alpha} \left( \frac{\alpha}{r_t} \right)^\alpha \frac{1}{1-\alpha-\gamma} N_{it} \int_{\hat{q}_{it}}^{\infty} q^{\frac{1}{1-\alpha-\gamma}} h(q) dq. \right] \quad (35)
\]

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

\[
p_{at} Y_{at} = (1 + \varphi) p_{at} c_{at} + N_{at} (F_{oat} + F_{qt}); \quad (36)
\]

and

\[
Y_{it} = (1 + \varphi) c_{it} + x_{it} + N_{it} (F_{oit} + F_{qt}), \quad i = m, s. \quad (37)
\]
2.5 Equilibrium

We are focusing on a decentralized economy with public sector intervention that takes as given the interest rate $r_t$ from the rest of the world. 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 social welfare, and where prices are the solution to the free entry conditions and market clearing.

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

$$K_t = \frac{\alpha w_t}{\gamma r_t}. \tag{38}$$

This permits 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 (19) for the manufacturing sector along with (38) pinned down the equilibrium wage rate and the stock of private capital. Output prices and plant-productivity thresholds are given by (21) and (24), respectively. Incorporating (5), (6), (15) and (16) into the market clearing conditions allows expressions (33) and (36) deliver expressions for the number of firms in each industry. Finally, motion equations (34) and (29), market clearing in manufacturing (37) and the public-investment optimality condition, expression (32), solve for the optimal consumption and investment patterns.

The above procedure 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 suggested by intertemporal condition (4). Rents extracted by politicians can be recovered from (30). At the firm level, the capital and labor allocations are obtained from equations (10), (11), (22) and (23).
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 impose that the price $P_{ct}$ of the consumption bundle grows at a constant rate at steady state. We do not make this assumption because it would constrain the values that could be assigned to the parameters and the capacity of the model to generate reallocations of resources among sectors. Nevertheless, it is interesting to look at the forces of growth in this particular scenario to have a deeper understanding of the model.

Therefore, let us denote by $Z_x$ the gross growth rate of variable $x$ along the BGP, and assume that $Z_G^{\beta_m-\beta_i} \frac{Z_{A_m}}{Z_{A_i}} = 1$, for $i = a, s$, so that $P_{ct}$ remains constant at steady state. In this scenario, the economy converges towards a BGP in which the feasibility constraint (27) suggests that the sectoral variables output value, private capital, and profits, the aggregate variables fixed costs and consumption, and rents, public infrastructure and investments all grow at the same rate as $Y_{mt}$. In addition, the definitions of sectoral capital and output expressions (28) and (??)– make clear that the individual the firm’s output value and its capital stock will grow at the same rate as $y_{mt}$ in all activities. According to (28), 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 (17) and (18) will take on the same number in all sectors. An important variable that will grow at the same rate as aggregate income per capita is the salary $w_t$.

We know that $Z_G = Z_{Y_m}$; which, using expression (21) that also holds for agriculture in long-run equilibrium, implies that the gross growth rate of output prices equals:

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

(39)
which is equal to one under our assumption. Notice that this suggests that output prices compensate for productivity differences so that the output revenues grow at the same rate in all sectors at steady state. Equation (39) along with production function (7) and inputs demands (11) and (12) imply that

\[ Z_{p_iy_i} = \left( Z_{A_m} Z_{Y_m}^{\beta_m - \gamma} \right)^{\frac{1}{1 - \alpha - \gamma}}. \]  

(40)

Next, notice that definition (28) of sectoral output requires that \( Z_{p_iy_i} = Z_{p_iy_i} Z_{N_i} \). Then, assuming for simplicity that \( \psi = 1/(1 - \alpha - \gamma) \), both expressions (17) and (18) deliver that

\[ Z_N = 1, \]  

(41)

and

\[ Z_{y_m} = Z_{Y_m} = Z_{A_m}^{\frac{1}{1 - \alpha - \beta_m}}. \]  

(42)

Growth rates \( Z_{y_m} \) and \( Z_{Y_m} \) depend on the path of technical change proxied by \( Z_{A_m} \). The bottom line is that the growth rate of infrastructure does affect the growth rate of output. In particular, along the transition, the level of infrastructure plays an important role in the determination of the economic growth rate and the level of income. This is true even though, as expressions (42) imply, the steady-state values of all growth rates are exclusively pinned down by the exogenous rates of population growth and technological change.

Finally, along the BGP, the Euler equation for consumption will give \( r_t \). More specifically, at steady state, expression (4) delivers that

\[ r_t = \frac{Z_{Y_m}}{\rho} - 1 + \delta_k; \]  

(43)

that is, the interest rate is determined by preferences and the economy’s growth rate.
4 The Brazilian Experience

We assign values to the model parameters so as to reproduce the evolution of sectoral variables in Brazil from 1995 to 2013. We focus on this middle-income Latin American nation because it is widely considered to be in deep need of further infrastructure investment. Looking for example at the Global Competitiveness Report 2016-17, Brazil's quality of overall infrastructure stands 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 fall compared to the 76th position achieved in the 2013-14 Report.

In addition, in line with our model, Brazil poor infrastructure status seems to be at least in part due to mismanagement of public investment. As Amann et al. (2016), among many others, argue, this inefficiency is related to Brazil's deficient regulatory governance that has deterred or delayed investment. A clear example of lost public capital as a consequence of bureaucratic barriers is given by World Bank (2012): 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 being the Petrobrás contractors' scandal in 2014. Contractors of Petrobrás, the state-controlled oil firm, payed billions of Dollars in bribes to political parties using corrupt intermediaries. Importantly, most contractors belonged to Brazil's largest infrastructure builders. Furthermore, 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.7

Our data on Brazil 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). In principle, we could access data

7Nevertheless, Brazil is not an extreme case of mismanagement according to the public investment efficiency index developed by Dabla-Norris et al. (2012). Brazil, with an index of 3.12 out of 4, ranks in second place within their sample of 71 low- and middle-income nations.
Figure 2: Sectoral shares of Brazilian gross value added (left chart) and firms (right chart) for all the variables from 1985. However, before 1995 the numbers look awkward. We can see this in Figure 2 that plots the shares of the three main sectors—agriculture, manufacturing and services—in gross value added (GVA, left chart) and in the number of firms (right chart) from 1985 to 2013. The former variable is supplied by IBGE and the latter by RAIS. We can see that data before 1995 show strange trends. In services, for example, the share of firms drops rapidly during this period, even though its GVA share grows probably too fast. The reason is probably the distortions generated by the strong hyperinflation suffered by Brazil between 1980 and 1994 that reached an annual inflation rate close to 3,000%.

As a consequence, we decide to focus on the time interval that starts in 1995 and ends in 2013. During this period, services have experienced an increase from 66.7% to 69.3% in its value added share, manufacturing a fall from 27.5% to 25%, and agriculture has remained relatively constant, moving from 5.8% to 5.7%. The share of firms depicts a similar picture, although now the primary sector 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 move now to the number of employees. Using data obtained from RAIS, Figure

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8 Following Herrendorf et al. (2014), agriculture includes cultivation and breeding of animals, plants and fungi; manufacturing captures all activity that falls outside of agriculture and services; and the category services refers to the tertiary sector.

9 An alternative source of data on gross value added is the Groningen’s 10-Sector Database. The sectoral shares shown by this alternative are very different from the ones supplied by IBGE before 1995. The numbers are, however, similar after that date.
Figure 3: Number of employees (left chart) and sectoral employment shares (right chart)

3 shows its evolution across sectors: the left-hand-side panel focuses on the absolute numbers, whereas the right-hand-side one gives the sectoral shares. The left chart shows that the total number of workers in Brazil went up from 23.5 to 49 million between 1995 and 2013. As expected, the number of employees grew faster in services, with an annual average growth rate of 4.6%. The same figure for manufacturing was 3.5%, and 2.2% for agriculture. The right chart, in turn, shows that the employment shares at the sectoral level followed relatively closely the evolution of the GVA ones. More specifically, the share of agricultural and manufacturing employment went down from 4 to 3% and from 28 to 24% during the same time interval, respectively; whereas the one in services rose from 68 to 73%.

Figures 4 and 5 present the evolution in the distribution of firms and the distribution of employees in each of the three sectors per firm size, respectively. The distribution is derived for each five-year period from 1995-1999 to 2010-2014. Firm sizes are also grouped into ten categories according to the number of employees (denoted by lit in the data legends). These categories go from zero employees, which means that only the owners provide labor services, to more or equal than 1000. In Figure 5 the category “lit = 0” does not appear because there are not hired employees in that group.

Focusing first in Figure 4, the distribution looks log-normal in each of the three sectors, as 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 4: Percentage of firms per firm-size in each sector

Figure 5: Percentage of employees per firm-size in each sector
the model economy has assumed. In addition, comparing across the four five-year intervals, it does not seem to have been significant changes over time. Nevertheless, we can see differences across industries. Agriculture is the one with a larger fraction of smaller firms, whereas manufacturing is the less skewed towards small sizes. For example, for the 2010-14 interval, about 70% of firms in agriculture have between one and four employees; this number compares to 42% and 57% in manufacturing and services, respectively.

Figure 5, does not show either significant changes over time in the distributions of employees. The exception is manufacturing, where the fraction 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 agriculture is concentrated in small firms, and the opposite occurs in manufacturing. In particular, more than 50% of agricultural employees serve firms with less than 20 workers. This contrast with manufacturing, where firms with 100 workers or more hire almost 60% of workers in that sector. Services 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 accounts in services for a larger percentage of workers (29%) than in manufacturing (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 workers per establishment in each sector. Agriculture
is the one with the smallest average firm, which has around five employees. Agriculture is followed by services, with an average firm that hires about thirteen workers. The largest establishments are located in manufacturing, with an average size that more than quadruples the one of agriculture. A closer look to the chart also tells that the average size has slightly decreased in all sectors. More specifically, in the primary, secondary and tertiary sectors the mean has gone from 5.8, 22.2 and 14.3 in 1995 to 5.5, 18.4 and 12.9 workers in 2013, respectively.

The coefficient of variation confirms the information obtained previously from Figure 5.\textsuperscript{11} In the right chart of Figure 6, we see that the most heterogeneous sector in terms of firm size is services. In this sector, we also observe a substantial decline in the degree of heterogeneity from 1995 to 2013. 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 seen in agriculture. Finally, although manufacturing has experienced a small increase in the coefficient of variation from 1996 to 2013, it remains the most homogeneous industry, with a biased towards larger firms.

Main messages:

5 Quantitative Analyses

This section first assigns values to the different parameters of the model. After that, we generate results from several policy experiments.

5.1 Calibration

We choose the interest rate so as to reproduce the average growth rate of real per capita GDP from 1995 to 2013 that, according to the Penn World Tables 9.0, has been equal to 3.4\% in Brazil. This implies an interest rate net of depreciation equal to 0.078. The growth rates of

\textsuperscript{11}The coefficient of variation is obtained from the data on the number of employees in each firm-size category assuming that within categories establishments have the same number of workers.
the sector-specific productivity parameters and their initial values are chosen to reproduce the Brazilian sectoral shares of GVA in 1995 and 2013. This gives \( A_{a1995} = 1, \ z_{Aa} = 0, \ A_{m1995} = 1, \ z_{Am} = 0, \ A_{s1995} = 1 \) and \( z_{As} = 0 \).

TBC

5.2 Results
TBC

6 Conclusion
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### 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 $i$ |
| $c_{i}$: consumption bundle | $L_{it}$: population size |
| $w_{i}$: wage rate | $q$: firm’s productivity |
| $r_{i}$: interest rate | $e_{it}$: quality of public infrastructure in sector $i$ |
| $b_{i}$: consumer’s stock of bonds | $e_{i}$: mean value of $e_{it}$ |
| $\tau_{i}$: lump sum taxes per capita | $\sigma_{e_{i}}$: standard deviation of variable $e_{it}$ |
| $p_{it}$: price of sector-$i$ products | $\omega_{i}$: weight of sector $i$ in consumption |
| $P_{it}$: consumption price index | $\eta$: utility scaling parameter |
| $l_{it}$: labor employed in sector $i$ | $\varepsilon$: elasticity of consumption |
| $k_{it}$: capital employed by sector $i$ | $\delta_{k}$: depreciation rate of physical capital |
| $K_{i}$: economy’s capital stock | $\delta_{g}$: depreciation rate of infrastructure |
| $y_{it}$: firm’s production in sector $i$ | $n$: population growth rate |
| $Y_{it}$: total production in sector $i$ | $\alpha$: share of capital in production |
| $c_{qi}$: fixed cost of entry | $\beta$: infrastructure share in production |
| $c_{fi_{it}}$: fixed cost of operation in sector $i$ | $\gamma$: share of labor in production |
| $\hat{q}_{it}$: productivity threshold in sector $i$ | $q_{1}$: lower bound of $q$ |
| $\pi_{it}$: firm’s profits in sector $i$ | $q_{M}$: upper bound of $q$ |
| $\pi_{it}$: economy-wide profits per capita | $c_{q_{i}}$: entry cost parameter |
| $I_{ki}$: investment in physical capital | $c_{f}$: operation cost parameter |
| $I_{gi}$: investment in public infrastructure | $\psi$: total fixed cost elasticity |
| $G_{i}$: stock of public infrastructure | $\phi$: population elasticity in fixed costs |
| $R_{it}$: rents captured by politicians | $\varphi$: weight of rents in welfare function |
| $N_{it}$: number of firms in sector $i$ | $\rho$: subjective discount factor |
| $Z_{xt}$: steady-state growth rate of variable $x$ |