The economic effects of financing private investments on R&D in Brazil[1]

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RESUMO

Os investimentos em pesquisa e desenvolvimento (P&D) têm desempenhado um papel fundamental na promoção de melhorias de produtividade e crescimento econômico. No Brasil, as atividades de P&D são fortemente dependentes do financiamento público e, na última década, houve uma tendência de queda nos investimentos em P&D no País. Este artigo explora os efeitos econômicos do financiamento público de investimentos em P&D no Brasil, levando em conta as mudanças na produtividade total dos fatores (PTF) nos setores de alta, média e baixa tecnologia. A análise procede de uma estratégia empírica em dois estágios integrados. No primeiro, estimou-se a elasticidade da PTF em relação aos investimentos em P&D. No segundo, simulamos uma retirada dos investimentos em P&D e da TFP vinculados ao financiamento público a partir de um modelo CGE baseado em P&D, que reconhece a relação fluxo-estoque entre investimento em P&D e capital do conhecimento. Sem o financiamento público de investimentos em P&D, as principais conclusões indicam um desvio do PIB real abaixo da trajetória de previsão da linha de base, afetando negativamente os mercados interno e externo da economia brasileira. Assim, haveria uma mudança na composição setorial do capital do conhecimento e investimentos em P&D, com perdas relativas nas indústrias de alta e média-alta tecnologia, tornando a base tecnológica do país mais dependente do setor público, especialmente para a educação.

Palavras chave: Financiamento público; P&D; Efeitos econômicos.

ABSTRACT

Investments in research and development (R&D) have played a key role in promoting productivity improvements and economic growth. In Brazil, R&D activities are heavily dependent on public funding and, in the last decade, there has been a declining trend in R&D investments in the country. This paper explores the economics effects of public R&D investment funding in Brazil, taking into account the changes on total factor productivity (TFP) in high-, medium- and low-technology sectors. The analysis proceeds from an empirical strategy in two integrated stages. In the first, we estimated the elasticity of TFP with respect to R&D investments. In the second, we simulate a withdrawal of R&D investments and TFP linked to public financing from an R&D based CGE model, which recognizes the stock-flow relation between R&D investment and knowledge capital. Without public R&D investment funding, the main findings indicate a deviation on real GDP below the baseline forecast path, negatively affecting both the internal and external markets of the Brazilian economy. There would be a change in sectoral composition of knowledge capital and R&D investments, with relative losses in high and medium-high technology industries, making the country's technological base more dependent on the public sector, especially for education.

Keywords: Public funding; R&D; Economic effects.

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1 Introduction

The rapid internationalization of production processes and markets over the last five decades has boosted the development and diffusion of new technologies in the world, affecting production and trade patterns (Athreye and Cantwell, 2007; Lam and Shiu, 2010; Mallidis et al., 2012). Production systems are increasingly fragmented and globally integrated (Los et al., 2015; The World Trade Organization, 2011). More technology-intensive economic sectors are growing and gaining participation in the world, leading to the outsourcing of activities in general and a rising demand for highly educated workers (Inklaar and Timmer, 2007). In this global scenario of accelerated pace of change, R&D investments are recognized as a key piece to influence and change the productivity levels and economic growth of a country (Grossman and Helpman, 1991; Jones, 1995; Romer, 1990). R&D investments can promote the production of knowledge and raise human capital levels (Becker 1964), generating gains in TFP and expanding physical capital stock. Evidence indicates that approximately 65% of productivity growth variance depends on R&D intensity, that is, gross domestic expenditures on R&D expressed as percentage of the GDP (Coccia, 2009). Given the recognition of these impact channels at the national and industry levels, tax incentives, subsidies, public expenditures (e.g., on patents, research projects and research institutions) and other forms of public capital support for R&D investments have become most popular and recurrent policy instruments in various nations (OECD, 2005). The challenge is to combine these policy instruments in order to make a given economic region more intensive in R&D (Ortega-Argilés, 2013). Coccia (2009) points out that an R&D intensity rate of between 2.3% and 2.6% would maximize its long-run impact on productivity growth. For example, the European Union, the United States and China achieved a rate of 1.95%, 2.74% and 2.05% in 2015, respectively (OECD, 2018). Nevertheless, at a much lower level, the Brazilian R&D intensity was 0.69% in 2016 (IBGE, 2017). Even so, this rate is slightly higher than that of developing countries such as Mexico (0.52), Argentina (0.61%) and Chile (0.38%) (OECD, 2018).

In Brazil, public financing funds are still scarce to meet the projects related to the innovation area of Brazilian companies (De Negri, 2012; Negri et al., 2009). In the last two editions of the Survey of Technological Innovation (Pintec), 2011 and 2014, elaborated by the Brazilian Institute of Geography and Statistics (IBGE, 2015a, 2013), public capital represented the second largest funding source for industrial expenditures on internal R&D activities and external acquisition of R&D in Brazil, a position behind inhouse-resource funding only. There are few empirical studies about the role of public R&D funding in the literature (Avellar, 2009; Avellar and Alves, 2008; De Negri, 2012; Kannebley Jr and Porto, 2012; Kannebley Júnior et al., 2016; Negri et al., 2009; Taveira et al., 2019). However, no applied research stresses the long-run economic repercussions of this policy instrument in Brazil. This type of analysis of impact on the overall economy is a complex task because requires a theoretical framework on knowledge stock and R&D investment (Bor et al., 2010). Our paper contributes to filling this gap and analyzes the economic deviations of public R&D funding from the Brazilian baseline forecast path up to 2025. To do so, our research simulates a withdrawal of R&D investments financed by public capital and the resulting effect on the TFP of the Brazilian economy, which may be observed between 2011 and 2016. To accomplish this task, we propose an articulation between an econometric model and dynamic R&D-based CGE (computable general equilibrium) model. Both models are pioneers and contribute to the literature highlighting the estimated TFP elasticity associated with R&D investment, as well as the role of public R&D funding in Brazil. Besides this introduction, this paper is comprised of five other sections. The second section briefly reviews previous research on R&D, productivity and public funding, presenting some CGE studies. The third section describes the econometric model and dynamic R&D-based CGE model, namely, the BIM (Brazilian Intersectoral Model). In turn, the fourth section covers the results of shock and the forecast of changes in the macro economy and sectoral structure over the next fifteen years. The sixth section presents the conclusions and remarks of the research.

2 R&D, productivity and public support

From the endogenous growth models, R&D investments have been incorporated as one of the factors that determine the productivity of the primary factors (Diao et al., 1999; Jones, 1995; Romer, 1990). Since R&D activity is one of the main channels of knowledge production, it can change the technical coefficients and the capital-labor ratio, generating technical efficiency, expanding the physical capital stock and reducing production unit costs for an economic activity (Bor et al., 2010). The literature about R&D and productivity is broad and indicated that R&D has a significant and positive effect on output growth, but with differentiated estimated R&D elasticities by sectors or nations, according to the detailed review of Ortega-Argilés (2013). A literature review of the period between 1969 and 2003 provides evidence that the estimated output elasticity of R&D varies from 0.05 to 0.60 for studies using individual firms, and from zero to 0.50 for sectoral studies, with a central tendency that ranges from 0.10 and 0.20 (CBO, 2005). In general, these econometric approaches assume a typical production function with quantities of the factors of production and, after estimation, the residual portion, which underlies Solow's (1957) productivity residual, could be regressed against the knowledge stock, an intangible asset. This approach began with Coe e Helpman (1995) and was applied to other empirical models (Adams, 1990; Krammer, 2014; Nishioka and Ripoll, 2012; O'Mahony and Vecchi, 2009).

On the other hand, several studies are turning to static and dynamic CGE models to analyze the economic effects of public R&D policy instruments and the relationships between knowledge development and economic growth (Bor et al., 2010; Bye et al., 2011, 2009; De and Ghosh, 2002; Diao et al., 1999, 1998; Ghosh, 2007; Hong and Lee, 2016; Křístková, 2013; Zürn et al., 2007). This category comprises CGE models based on Romer's (1990) endogenous growth theory, which associated knowledge capital and R&D investment. The concern of applied research is to explore the direct and indirect channels of production and consumption links established by the theoretical and data framework of the CGE models. In general, most studies have implemented CGE models with the explicit recognition of knowledge capital as an additional primary factor, so that changes in TFP explain the performance of the economy better than standard CGE models (Hong et al., 2014). This inclusion of knowledge capital prevents the effects of R&D investments on productivity from being overestimated (Meriküll et al., 2013). Already CGE models in their recursive dynamic version have been used to evaluate policy effects on the baseline forecast path of an economy. In these types of modeling, knowledge capital is accumulated temporally according to R&D investments by a new perpetual inventory method, in which the allocation of R&D investment follows the logic of Tobin's Q. For example, Ghosh (2002) analyzed the effects of direct subsidies and commercial incentives on TFP. Bor *et al*. (2010) examined the impacts of public R&D investment and TFP on the Taiwanese economy. Hong and Lee (2016) used a knowledge-based CGE model to analyze the effects of tax credits on R&D investment according to firm size in the South Korean manufacturing industry.

3 Empirical strategy

Our analysis of the public R&D funding policy in the Brazilian economy proceeds in two stages. In the first step, a residual TFP function is estimated as a measure of technical efficiency gains against industrial R&D investments in Brazil between 2010 and 2016. At this stage, our innovation lies in computing this information for the 67 economic sectors of the Brazilian economy annually and based on the tables of the System of National Accounts (SNA) of IBGE and the gross fixed capital formation matrix or capital flow matrix (CFM) estimated by Miguez (2016), whose version was update by Miguez and Freitas (2019). The estimated TFP elasticity of R&D investment is used to simulate productivity losses in a scenario with absence of R&D investment associated with public funding in the second stage. Thus, both TFP changes and reduction in R&D investments will be political shocks in a dynamic CGE model. This two-step integration allows us to consider some spillover effect underlying R&D activities in the CGE model. This model follows some applied studies (Bor et al., 2010; Hong et al., 2014; Křístková, 2013). Our present model does not capture the innovation and productivity spillover from R&D activities, but such strategy between the CGE and econometric models partly mitigates such deficiency. However, this empirical articulation allows to treat the links between R&D investments and TFP changes explicitly. Moreover, we can compare the impact of TFP and R&D investments in Brazil up to 2025.

3.1 The estimation model

In order to obtain the relationship between technology and R&D investments in the Brazilian economy, we initially adopt a typical Cobb-Douglas production function, in which only the supply of the production factors is exogenous in relation to the productive process in the short-term. In this function, the technology represents a residual contribution to production and it is not measured by primary factors (Solow, 1957). That is,

$$Y_{it} = A_{it} K_{it}^{\alpha_K} L_{it}^{\alpha_L} \tag{1}$$

where Y_{it} is the output of sector $i = (1,...,67)$ in $t = (2010,...,2016)$; K_{it} and L_{it}^{L} are the capital and labor employed in production, respectively; and α_K and α_L are the elasticities of capital and labor, respectively. The term A_{it} is a technology index (TFP), which encompasses other latent factors in the production function. Taking logarithms and defining TFP as a measure of effects in total product caused by technological improvements, equation (1) can be redefined as:

$$y_{it} = \alpha_0 + \alpha_K k_{it} + \alpha_L l_{it} + \varepsilon_{it} + \gamma_{it} \tag{2}$$

where $y_{it} = \ln Y_{it}$, $k_{it} = \ln K_{it}$ e $l_{it} = \ln L_{it}$. Thus, $\ln A_{it} = \theta_{it} = \alpha_0 + \varepsilon_{it} + \gamma_{it}$, γ_{it} being an idiosyncratic error term. Then, we estimated the coefficients $\hat{\alpha}_0$, $\hat{\alpha}_K$ e $\hat{\alpha}_L$ to obtain TFP residually by $\theta_{it} = y_{it} - \hat{\alpha}_K k_{it} - \hat{\alpha}_L l_{it}$. In the second stage, this residual portion (θ_{it}) is regressed against R&D investment (w_{it}):

$$\theta_{it} = \beta_0 + \beta_z w_{it} + v_i + u_{it} \tag{3}$$

where w_{it} is the natural logarithm of R&D investments. This estimation model follows the steps and procedures of Krammer (2014) and Messa (2015) considering a panel data structure. For the estimation of equation (2), we adopted the fixed effects model, which controls for fixed effects at the sector level; that is, it does not require that the explanatory variables be uncorrelated with the effect not observed (term). The estimation of equation (3) was also performed by fixed effects. The underlying assumption is that the R&D investment effect has a contemporary effect on TFP. Nevertheless, the idiosyncratic error (μ_{it}) was tested to verify the presence of serial correlation.

The measure of the output (Y_{it}) in this analysis is value added, whose values were obtained from the IBGE's System of National Accounts (SNA)[2] and deflated for the year 2010. Labor (L_{it}^{L}) is measured by the number of employed personnel in the sectors (SNA). The physical capital stock was constructed by the perpetual inventory method, taking into account the CFM estimated by Miguez and Freitas (2019). For this, we compute the gross rate of return on capital and the annual depreciation rate with data on gross fixed capital formation (GFCF), without R&D, gross operating surplus (GOS) and capital stock provided by the Institute for Applied Economic Research (Ipea, 2017). In 2010, the gross rate of return on capital was 20% for all

[2] Since 2010, the SNA Supply and Use Tables have presented R&D expenditures within the gross fixed capital formation vector (GFCF) according to the new asset boundary (including intellectual property products), and as a product in the intermediate consumption matrix and the production of the R&D activity. The availability of this R&D information is limited until the year 2016 and, therefore, the data for the other variables in the two-stage econometric model are restricted to this time interval (2010 to 2016).

sectors, i.e., this rate to capital was calculated as the ratio of GOS relative to initial capital stock. The sectoral composition in GOS is different from that of the CFM of Miguez and Freitas (2019).

On the other hand, R&D expenditures are divided between public and private. The total public R&D output[3] is defined as non-mercantile (or intangible asset) and exclusively absorbed by the GFCF. In turn, the private R&D output is classified between mercantile and non-mercantile. The mercantile share is absorbed by intermediate input-output, whereas the non-mercantile output is also allocated to GFCF (IBGE, 2015). In the SNA, the annual average of the non-mercantile portion was only 6% of the total Brazilian R&D output between 2010 and 2016. Moreover, the Pintec provides information on net sales revenue, as well as on the expenditures on internal R&D activities and external acquisition of R&D by the main private sectors. In order to make the sectoral distribution of private R&D investments feasible and to evaluate the consistency of information, we elaborated two vectors for each year: $\mathbf{a} = \{a_i\}$, where the coefficient a_i is obtained by dividing R&D expenditures in relation to net sales revenue, both from the Pintec; $\mathbf{b} = \{b_i\}$, where b_i is computed from the ratio between private R&D output and total output for all sectors of the SNA.

When sectorally compared, the coefficients in these two vectors are very close. Only Petroleum Refining and Biofuel activities presented positive coefficients in vector $\mathbf{a}$, but null in $\mathbf{b}$. Then we chose to consider these two positive coefficients because they are traditionally R&D-intensive economic activities in the country. Two sectoral coefficients were added within $\mathbf{b}$, namely $\mathbf{b}^*$, which presented a higher level of sectoral detail and, therefore, was more heterogeneous internally. The real value of private R&D investment was, therefore, distributed according to the sectoral structure of a vector of elements originally calculated by weighting the coefficients of $\mathbf{b}^*$ and the total output of each activity.

3.2 The CGE model

Our study developed a computable equilibrium model capable of analyzing the effects of investment policies on the Brazilian economy. The model was named R&D-based BIM and extends the theoretical specification of capital accumulation and the relationship between the rate of return on capital and investments of the Orani-RD model. Capital stock is decomposed between physical and knowledge capital, which present a lagged adjustment to the respective investments. We are assuming a one-year gestation lag. In the main mechanism of recursive dynamics, there is a new stock-flow relation between R&D investment and knowledge capital, similarly to Bor et al. (2010) and Hong and Lee (2016). In addition, investors produce new units of physical and knowledge capital demanding input in different ways, whose data structure is derived from the distinct investment allocation behavior in the CFM of Miguez and Freitas (2019).

3.2.1 Theoretical framework

The demand behavior of the producers, investors, and typical household represents a nested structure by assigning the assumption of weak separability (Dixon et al., 1982). Figure 1 depicts this nested structure. At the top level of the production structure (Figure 1a), industries produce one or more goods demanding intermediate inputs composites (X_i) and added value composites (V_i) in fixed proportions. At the second level, all the composites are derived from a constant elasticity of substitution (CES) function aggregation. Each intermediate input composite is formed by an imperfect substitution (Armington, 1969) depending on the relative prices between domestic (D_i) and imported inputs (M_i). The value added consists of an aggregate formed from the imperfect substitution via price between labor (L_i), land (T_i), physical capital $(K_{F,i})$ and knowledge capital $(K_{H,i})$. Thus, in both types of composites, changes in the relative prices among primary

[3] Such as: Public Administration, Defense and Social Security, Public Education, and Public Health.

factors or between intermediate inputs induce imperfect substitution in favor of relatively cheapened inputs (cost-minimizing assumptions). This nested structure of two-level production is defined by:

$$Z_i = \min\left(\frac{X_i}{a_i^X}, \frac{V_i}{a_i^V}\right) \tag{4}$$

where $V_i = \left[\sum_{i=1}^{f} \delta_{f,i} V_{f,i}^{-\rho^V}\right]^{\frac{-1}{\rho^V}} \forall \quad f = (L, T, K_F, K_H)$ and $X_i = \left[\sum_{i=1}^{s} \delta_{s,i} X_{s,i}^{-\rho^X}\right]^{\frac{-1}{\rho^X}} \forall \quad s = (D, I)$

The terms a_i^X and a_i^V represent productive efficiency by composite; δ is a participation parameter that satisfies $\sum_{i=1}^{f}\delta_{f,i} = 1$ or $\sum_{i=1}^{s}\delta_{s,i} = 1$, while ρ represents a substitution parameter within each composite (X_i, V_i) by industry. Although the theoretical specification is identical for all sectors, the substitution elasticities and the proportions of inputs and primary factors may vary among them.

Figure 1 – Main theoretical nested structures

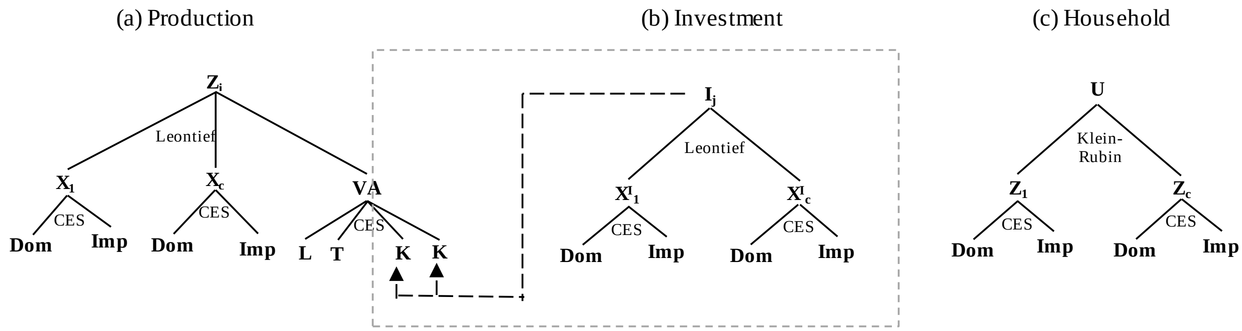


Figure 1b shows the forms of capital creation. The inputs used for capital creation are also subject to the investor's cost-minimization problem. Similarly to the production structure, investors combine intermediate input composites by a Leontief function at the first level. In each composite, a CES function controls the arrangement of domestic and imported inputs. As in Hong et al. (2014), the investor uses only the domestically produced R&D to create knowledge capital $(I_{K_H,i})$, because imported R&D is absent in the BIM database. Public activities demand their own R&D output to create knowledge capital, whose specification is in accordance with IBGE (2015). Yet, no primary factors are used directly as inputs for the formation of physical and knowledge capital. The requirements for production factors are recognized in the value added of the productive suppliers of physical investments and R&D, respectively. The structure of investments is determined as:

$$I_{j,i} = \min\left(X_{j,i}^I\right) \quad \forall \quad j = (K_F, K_H) \tag{5}$$

where $X_{j,i}^I = \left[\sum_{i=1}^{s} \delta_{s,j,i}\left(X_{s,j,i}^I\right)^{-\rho}\right]^{\frac{-1}{\rho}} \forall \quad s = (D, I)$, which are the similar parameters of equation (4).

In the main recursive mechanism of the model, physical $(I_{K_F,i})$ and R&D $(I_{K_H,i})$ investments are treated in the capital accumulation function by a conventional perpetual inventory method with constant rate of depreciation:

$$K_{j,i,t+1} = (1 - dep_{j,i})K_{j,i,t} + I_{j,i,t} \quad \forall \quad j = (K_F, K_H) \tag{6}$$

Both capital-accumulation methods are similar. The allocation of investments proceeds by following the logic of Tobin's Q (Hong et al., 2014), So, the expected rate of return is a positive function of the ratio between the unit rental price and the unit asset price of capital, i.e., $E_{j,i} = f(R_{j,i} / P_{j,i}^{I})$. Thus, in a logistic function, the gross rate of growth of each type of capital in the next period is defined by:

$$G_{j,i} = \frac{U_{j,i} G_{j,i}^{Tend} \left(M_{j,i}\right)^{\xi_i}}{U_{j,i} - 1 + \left(M_{j,i}\right)^{\xi_i}} \tag{7}$$

in which $G_{j,i}^{Tend}$ is the growth trend of capital stocks in the economy, $U_{j,i}$ represents an exogenous term, so that it limits a maximum value for the gross rate of capital growth next period: $G_{j,i} = U_{j,i} G_{j,i}^{Tend} = G_{j,i}^{\max}$; ξ_i is an investment elasticity; and $M_{j,i}$ measures the relation between the expected rate of return $(E_{j,i})$ and the normal rate of return $(R_{j,i}^{Normal})$ of capital *j* for investor *I*; that is, $M_{j,i} = E_{j,i} / R_{j,i}^{Normal}$. Thus, the growth rate of capital *j* in sector *i* $(G_{j,i})$ will exceed its respective growth trend $(G_{j,i}^{Tend})$ if, and only if, the expected rate of return $(E_{j,i})$ surpasses the investor's normal rate of return $(R_{j,i}^{Normal})$. This circumstance is verified mainly in the short-term (Dixon and Rimmer, 2002). The structure enclosed by a dotted box in Figure 1 establishes the link between the growth rate of each capital stock and corresponding investment, which is guided by rates of return.

In turn, households determine an optimal composition of their consumption "baskets" from a linear expenditure system (LES) derived from Klein-Rubin (1947), subject to a budget constraint (see Figure 1c). The LES function is mathematically expressed as:

$$U(Z_1, \ldots, Z_c) = \sum_{i=1}^{c} S_i^{Lux} \ln(Z_i - Z_i^{Sub}) \tag{8}$$

where Z_i is the total demand for the good i; Z_i^{Sub} represents expenditures on necessary goods (subsistence); $Z_i - Z_i^{Sub}$ is a residual of the consumer's budget and identifies product *i* as a 'luxury' or 'supernumerary' good, which varies according to consumer income; and S_i^{Lux} denotes the share of this residual allocated to each luxury good relative to total luxury expenditure — the marginal budget shares. The demand for luxury goods depends on household income and the relative prices of the products, affecting the scale of consumers' utility function. Households also act rationally in the choice between domestic and imported goods through a CES technology.

Finally, the model assumes the small economy hypothesis in international trade, meaning that changes in the Brazilian foreign trade do not influence international prices. The export demand is inversely related to that traditional commodity's price with constant exchange rate, but it is positively affected by the exogenous expansion of international income. Government demand is exogenous, and it may or may not be associated with household consumption or tax collection. Inventories are accumulated according to production variation. Finally, there is a lagged adjustment process in the labor market, between real wage growth and national employment supply. Therefore, we assume that while employment is above its forecast level due to policy shocks, the real wage rate moves further and further above its forecast level. This suggests that the shocks which are unfavorable to labor produce short-term decreases in employment and long-term decreases in real wages (Dixon and Rimmer, 2002).

3.2.2 Data structure and calibration

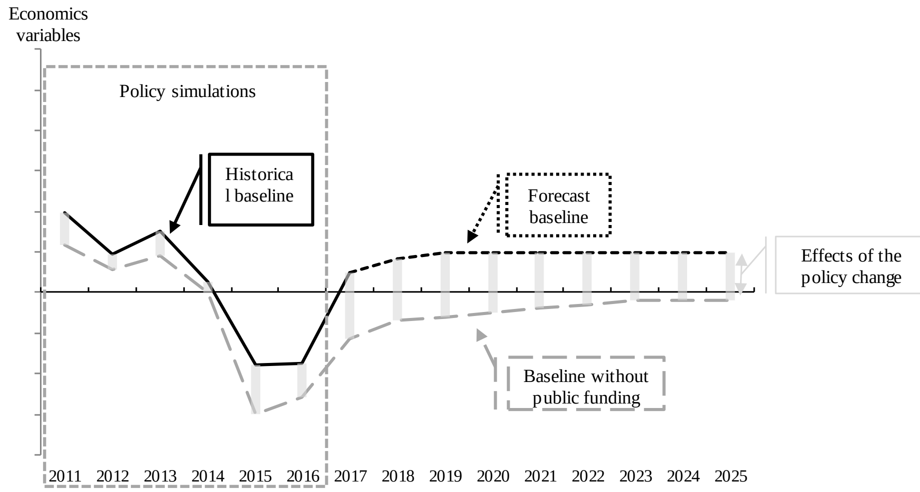
The BIM model represents the supply and demand side of commodity and factor markets and is specified as a system of linear equations, and solutions of the underlying levels equations are obtained in percentage change form and in deviations from an initial solution – Johansen type (Johansen, 1960). In its dimensions, there are 67 sectors which produce one or more commodities using as inputs domestic and imported commodities and five primary factors (i.e., labor, land, physical capital and knowledge capital). The model also contains other representative agents – 65 investors, one household type, government, foreign consumer and inventories. There are 4 margins, split between one retail trade and three freight transport services (road, rail, and waterway). These margins are required proportionally for each market transaction (the movement of a commodity from the producer to the purchaser). The costs of the margins and indirect taxes are included in purchasers' prices but not in basic prices of goods and services. The core database is based on the 2010 Brazilian Input–Output Matrix (IBGE, 2010). The database shows that, in 2010, the R&D product accounted for 0.53% of the total production and 52.47% of the total R&D output came from the public sector. The R&D product sells about 94% of its output to investment (not mercantile) and 6% to intermediate consumption. The country does not import R&D.

Some behavioral parameters were calibrated according to the CGE models of Domingues et al. (2014) and Betarelli Junior & Domingues (2014). The steady state was defined as 2.4%, whose rate represents the average annual growth of capital stock between 2000 and 2016. We assumed a knowledge capital depreciation rate of 15%, which is similar to some studies (see Nadiri and Prucha 1996; Hong et al. 2014). Zawalińska, Tran, & Płoszaj (2018) conclude that R&D stock depreciation rates are at least two times higher than those of physical capital. For a knowledge capital depreciation rate of 15% and steady state of 2.4%, the trend ratio between R&D investment and knowledge capital stock was 17.4%, with the gross rate of return on R&D investments being about 20%, with a net rate of return of 5%. Following Nishioka & Ripoll (2012) and Krammer (2014), the initial knowledge capital stock was estimated by dividing sectoral R&D investments by the sum between depreciation rate and average growth rate of real investment. Lastly, the ratio of physical investments relative to physical capital stock was 8.3%, resulting in a depreciation rate of almost 6% with steady state of 2.4% as well. Given that the physical investments and the gross operating surplus (GOS) associated to physical capital presented distinct sectoral structures, the gross rate of return oscillated up to 20% across industries.

4 Closure, policy analysis and results

Recursive dynamic models produce sequences of annual solutions linked by dynamic mechanisms such as physical capital accumulation. Policy analysis represents the comparison of two alternative sequences of solutions. The first sequence is created without policy change and presents a base forecast for the future (baseline closure). The other sequence has policy change in place. Thus, baseline projection serves as a control path from which deviations are measured in evaluating the impacts of the policy shock (Dixon and Rimmer, 2002). Figure 2 depicts these differences and sequential solutions from the baseline and policy simulations. Historical (observed) and forecasting simulations form the baseline scenario (i.e. reference scenario). Our policy simulations are applied between 2011 and 2016. Since all the investments were simulated in the baseline, we implemented a policy of cuts in those private R&D investments linked to public financing with effects on TFP. Therefore, we have the effects of the policy change as deviations in the economic variables of the baseline scenario. This type of policy simulation offers two analytical perspectives. First, this analysis indicates what would have been the positive effect of public policy for the Brazilian economy to reach the reference scenario until 2025. This positive effect on an economic variable is given by the difference between historical and forecast baseline and baseline without public funding (Figure 2). Second, the analysis presents also the negative deviations of the economic variables in relation to the baseline that were caused by the cuts in private R&D investments associated with public financing. Both cases present a reciprocal way of quantifying the role of public R&D funding in Brazil. In summary, if we are evaluating the negative deviation from the baseline, we are also pointing out the positive effect of the same policy to raise the reference baseline. We chose to present the second way of analysis, that is, the negative deviations of the policy from the scenario.

Figure 2 - Baseline and policy simulations



Moreover, in the baseline closure, we assumed that the main macroeconomic aggregates are exogenous, such as real GDP, investment, household consumption, government demands, export volume and aggregate employment. This choice is necessary to accommodate observed and forecast variations in these macroeconomic indicators. Conversely, some macro variables are swapped and endogenous (shift in final demand, national wage and TFP). Variables of corresponding normal rates of return are also endogenous to accommodate observed changes on physical and R&D investments. The observed and forecast shocks to the main macroeconomic indicators in the baseline scenario are reported in Table 1.

Table 1 - Real changes (%) of the main macroeconomic indicators

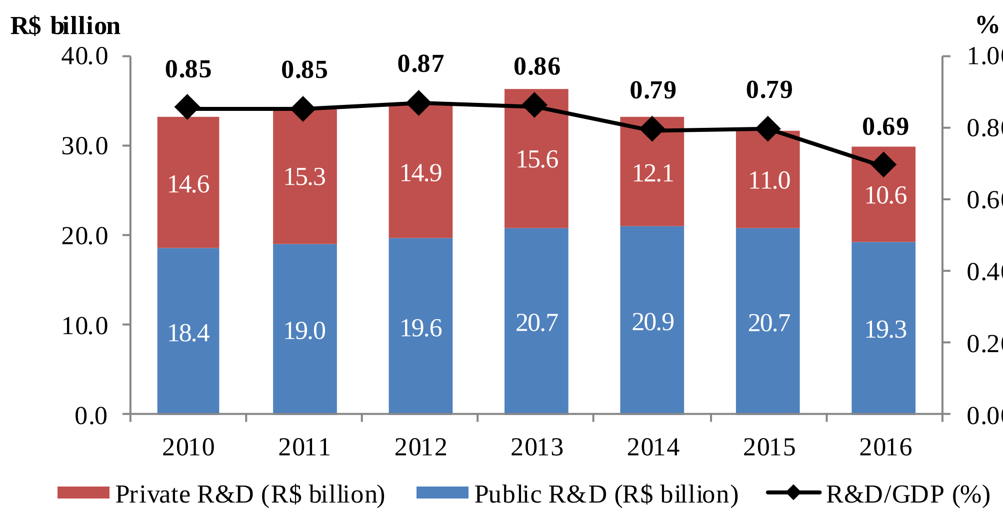
Indicators	Observed							Forecast	
	2011	2012	2013	2014	2015	2016	2017	2018	2019-2030 (year-to-year)
GDP	3.97	1.92	3.00	0.50	-3.55	-3.46	1.00	1.70	2.00
Household consumption	4.82	3.50	3.47	2.25	-3.22	-4.30	-0.60	1.50	1.50
Government demands	2.20	2.28	1.51	0.81	-1.44	-0.06	-0.56	0.70	0.70
Exports	4.79	0.27	2.39	-1.13	6.82	1.92	5.18	4.60	4.60
Investment	6.83	0.78	5.83	-4.22	-13.95	-10.30	-3.70	1.70	1.70
R&D (K_H)	3.46	0.76	5.39	-9.04	-4.10	-5.94	-3.70	1.70	1.70
Physical (K_F)	6.98	0.78	5.85	-4.02	-14.36	-12.42	-3.70	1.70	1.70
Employment	1.47	1.41	1.56	2.86	-3.34	-2.10	2.00	2.00	2.00
Population	0.97	0.94	0.90	0.87	0.83	1.00	1.00	1.00	1.00
Imports price index, C.I.F.	14.28	0.95	-1.17	-1.97	-11.88	-8.94	4.06	3.00	3.00

Source: System of National Accounts (IBGE); Foreign trade studies center foundation (Funcex); BNDES (2018).

The observed data comprise IBGE SNA statistics. Changes in import prices are obtained from the Foundation for Foreign Trade Studies Center (Funcex) for the years 2011 to 2016. In 2017, physical investment and R&D are the same as aggregate investment, as the SNA Tables for 2017 will only be announced by the end of 2019. The forecasts for the macroeconomic scenario follow the BNDES forecast report (2018). In general, the macroeconomic information shows that in the 2011-2016 period, there was a slowdown in the Brazilian economy, with sharp declines in domestic demand components in 2015, such as household consumption, investments and government expenditures. In the same period, exports started to register significant growth, when compared with those of 2014. This recessive scenario should be maintained between 2016 and 2018 and the recovery is expected after this period. Exporting sectors will be the first to recover due to the scenario projected for the Brazilian economy. Productive activities which are highly dependent on internal market dynamics must face slower recoveries until 2025.

Physical and R&D investment paths were similar to the aggregate investment between 2011 and 2016. Public R&D participation was increasing and relatively higher than private R&D, reaching 64.5% in 2016, an increase of 9 percentage points (p.p.) in relation to 2011 (Figure 3). Despite this greater share in R&D composition, the real expansion of the public sector was only of 1.5% between 2011 and 2016. Private R&D decreased almost 31% in the same period, and its fall affected the Brazilian R&D intensity by 0.69%, i.e., a decline of 0.16 p.p. when compared with 2011. Thus, the technological base of innovative companies has retracted in the country, evidencing that public R&D funding can be an alternative to reverse this declining trajectory. For the United States, for example, Goel et al. (2008) indicated a larger role of federal R&D relative to non-federal R&D in growth. When we analyze public R&D expenditures in the last two editions of the Pintec (2011 and 2014), it can be observed that it accounted for 13.8% of the total private R&D in Brazil. The manufacturing industry is the sector that received public funding the most (15.1%) in the 2012-2014 triennium, followed by service activities (9.5%). Overall, industrial sectors often occupy an important role in the economy for some reasons. First of all, their greater capital intensity allows greater potential for productivity gains due to the technology absorption incorporated in new machines and equipment. Second, industrial activities are seen as a key source of innovations for the productivity of other sectors, despite the growth of certain services as innovation sources. Finally, this type of sector is traditionally perceived as a source of higher quality jobs and lower turnover, which enables the development of specific human capital with a positive impact on productivity (Messa, 2015).

Figure 3 – Brazilian R&D investments (in constant 2010 price)



Source: System of National Accounts (IBGE).

These public financing shares in relation to the total R&D expenditures of the last two editions of the Pintec (2011 and 2014) were used to elaborate policy shocks. To do so, after a correspondence with the 67 productive sectors of the BIM model, a simple weighted mean of the participation of public financing and the R&D investment by the private sector was calculated. This weighting calculation allowed the investment value to be associated only with public financing in each year. Given that the 2014 Pintec provides values declared in the last year of the triennium, we assigned the share of public funding in 2012 and 2013 as being an average of those observed in the 2011 and 2014 Pintec. In 2015 and 2016, there was the same percentage reported in the 2014 Pintec. Table 2 displays the annual variations in R&D investment made from public financing by activity, highlighting technological intensity following OECD (2011) criteria. High and medium-high technology-intensive sectors were those most demanding of public financing between 2011 and 2016, with an annual average of 15.6%. These are industrial activities with the largest participation in private R&D investments in 2016 (10.6%). On the other hand, knowledge-intensive business services (KIBS) showed a 10% public contribution for R&D investments, being the second most representative of the private R&D distribution in the Brazilian economy. We simulate a policy shock of falling private R&D investments in proportion to the public funding shortfall, considering that the domestic R&D product is associated exclusively with the formation of knowledge capital in the CGE model, without a close substitute. The portion of public funding used includes all current policies in Brazil: Innovation Law (Law 10.973 / 2004) and the Law of Good (Law No. 11,196 / 2005) Brazilian National Research Council (CNPQ), venture capital programs from the Brazilian Development Bank (BNDES) and the Brazilian Innovation Agency (FINEP).

Table 2 –R&D investments and public funding share

Productive activity	R&D investment (R$ million in constant 2010 price)						Share of public funding (% in total private R&D investment)					
	2011	2012	2013	2014	2015	2016	2011	2012	2013	2014	2015	2016
Industry*	9704	9777	9189	9765	7375	6498	12.54	13.03	12.98	13.82	12.55	12.26
Low	648	738	719	738	739	688	15.53	15.45	15.64	14.63	15.67	15.71
Average Low	3264	3400	3222	3406	2691	2479	8.22	7.29	7.27	6.82	6.46	6.46
Average High	4596	4477	4215	4511	3197	2663	14.20	16.43	16.33	18.96	16.38	16.13
High	1206	1171	1042	1119	769	686	16.35	15.11	15.13	13.75	14.54	14.36
Services**	23378	24449	25295	26577	25681	25203	1.44	1.84	1.87	1.97	1.62	1.56
KIBS	3794	4235	4489	4513	3527	3317	7.71	9.52	9.51	10.74	11.30	11.32
Other services	1126	1240	1246	1313	1214	1184	3.72	3.68	3.55	2.90	1.45	1.46
Public administration	18448	18966	19552	20742	20919	20683	-	-	-	-	-	-
Total	**33082**	**34226**	**34485**	**36342**	**33056**	**31701**	**10.61**	**11.29**	**11.15**	**12.00**	**11.05**	**10.79**

Source: System of National Accounts and Pintec (IBGE).
Note: * Technological intensity (OECD); ** knowledge intensive services (KIBS).

Therefore, it is expected that KIBS, high and medium-high technology-intensive industries, as well as its productive suppliers, will be the ones most impaired by the cut of public financing in private R&D. These values will represent the reduction shocks on private R&D investment in policy closure between 2011 and 2016. A closure swap was made, that is, the R&D investment variable became exogenous to receive the policy shock and normal rate of return variable became endogenous. The reduction of private R&D investments due to the absence of public financing has a negative effect on TFP in the Brazilian economy. In this variant, our study estimated the equation (2) to obtain TFP residual or the not observed effect (first stage), whose variable is then regressed against R&D investments (second stage), according to equation (3). Both stages were estimated by fixed effects at the economic sector level. Table 3 provides the results of this 2-stage econometric model with the Durbin-Watson test statistics modified by Bhargava et al. (2006) and Baltagi-Wu statistics (Baltagi and Wu 2002). Although the probabilities are not presented, the comparison of the values with the confidence intervals suggests the existence of serial correlation (AR1) in the disturbances. In order to deal with this, equation (3) was estimated by (within) fixed effects, assuming that the disturbances follow an AR (1) process.

Table 3 - Estimates of the 2-stage econometric model for Brazil (2011-2016)

Variables	First stage (y_{it})[1]	Second stage(θ_{ij})[2]
Constant	3.8509***	-0.0555***
	(0.6382)	(0.0120)
Physical capital (k)	0.0081	-
	(0.0152)	
Labor (l)	0.4744***	-
	(0.0471)	
R&D Investment		0.0151***
		(0.0061)
N	476	408
R^2 *within*	0.2000	-

Source: Research results.

Note: *** p <0.01. Robust errors are reported in parentheses; [1] "dependent variable = y_{it} (ln of value added), R2 within = 0.200; [2] dependent variable = θ_{it} (TFP), Bhargava modified Durbin-Watson test = 0.6327 and Baltagi-Wu LBI test = 1.1354.

The result found indicates a TFP elasticity of 0.015 with respect to R&D investments (Table 3), which is well below the rate found in developed countries. Based on estimates for sectoral data, Bartelsman (1990) estimated the R&D elasticity as ranging from 0.11 to 0.15 in the 1958-1986 period for the US, whereas Coe and Helpman (1995) found an elasticity of 0.23 for G7 countries. The elasticity for the Brazilian economy is closer to estimates for OECD countries not participating in the G7, which was estimated at 0.08 (Coe and Helpman, 1995), or earlier estimates for Australia, for which elasticity was estimated to be 0.02 in the 1975-1991 period, according to the Australian Industry Commission (1995) report. On average, our estimation result is within the estimated range in these studies. The estimated elasticity in our paper will be weighted by the negative variation of private R&D investments in a scenario of absence of public financing. This percentage will be simulated as TFP effect for each activity sector. For that, the shocks were applied in the technological variable a_i^V of equation (4) between 2011 and 2016, as in Křístková (2013). So, GDP movements depend both on changes in the TFP itself and on changes in capital stock and employment, which in turn depend on many factors apart from changes in R&D stock.

4.1 Results

Figure 4 illustrates the main causal relationships underlying the aggregate results of the model. According to the structure of the model, without public R&D funding, investors would find greater constraints to produce new units of knowledge capital. Lower R&D investment demand generate a direct reduction in the output of R&D-producing activities. Accordingly, the input requirement per unit of output decreases, causing a negative impact on the primary factors and prices of intermediate inputs in the economy. Given the possibility of substitution among the primary factors, the cut in public development would alter relative prices, leading to a shift in demand toward the relatively cheaper primary factor. Moreover, investors foresee potential lower returns and household income and consumption are lower. Nevertheless, production costs generate a reduction in the prices of composite commodities, transmitted by sectoral interdependencies (price effect). In a cost-competitiveness approach, some producers become more competitive (production costs go down), encouraging the external demand especially – which requires more intermediate inputs and primary factors and, thus, reasonably pushes up input prices. Labor-intensive and/or traditionally exporting activities would start to sell more abroad, mitigating the initial negative effect on internal demand. Again, these certain positive effects are transmitted to other markets of the economy (activity effect), with the increase in production costs being reinforced by TFP in R&D-demanding activities, because the productive processes begin to require relatively more primary factors per unit of output (i.e., the unitary cost declines with the expansion of production). The competitiveness of domestic products in the economy decreases. Therefore, the productive inefficiency associated with cutting private R&D investments affects not only the internal market, but also long-term external demand.

Figure 4 – Causal relations underlying the system of equations of the CGE model

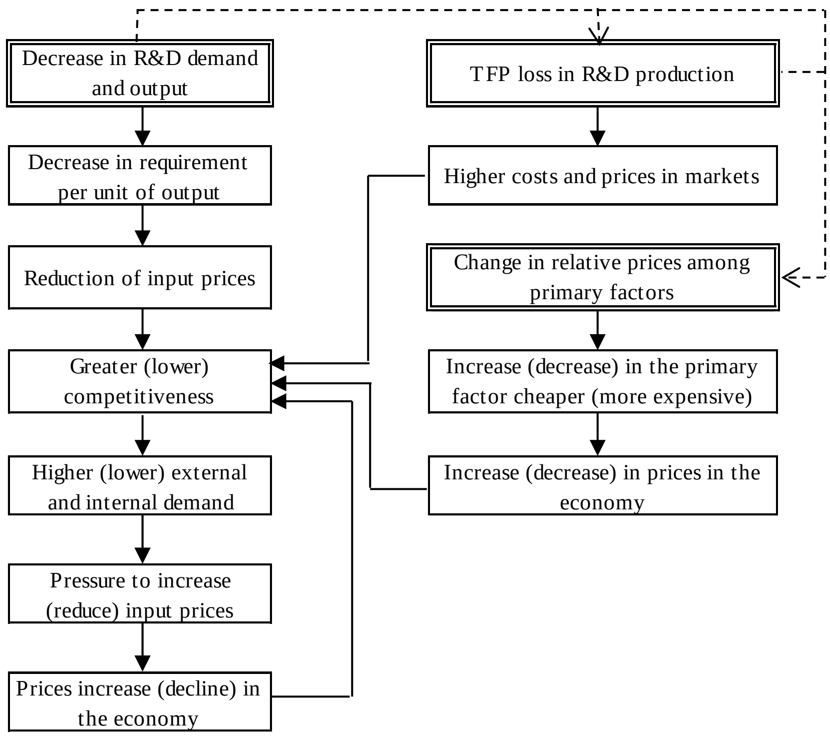


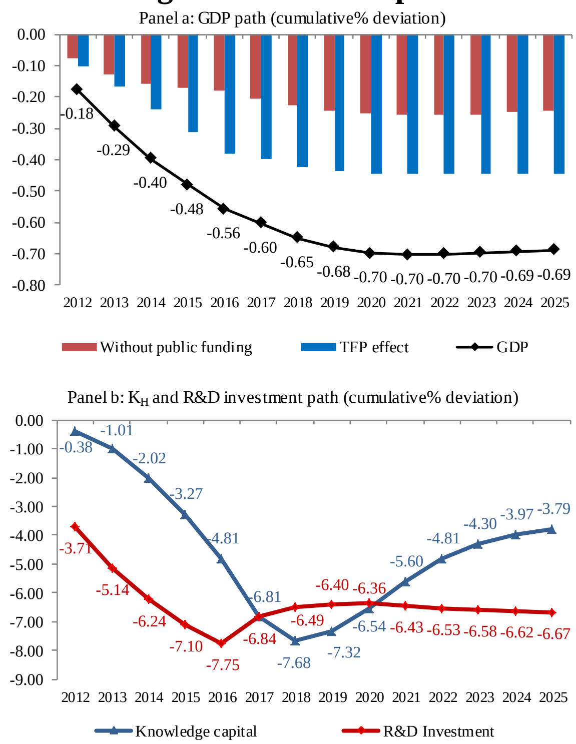
Table 4 provides the deviations from the main macroeconomic indicators provided by the policy in relation to the baseline forecast, considering the separate effects of the absence of public R&D funding and the subsequent withdrawal on TFP. The absence of public R&D funding and the reduction in associated TFP have a negative impact on the GDP growth rate between 2011 and 2016, slowly decelerating over time. The declining in the time path of deviations in the GDP and other macroeconomic variables is due to the lagged movement of the real wage and the capital stock (e.g., Figure 5, Panel a). Together, both simulations led to a shrinkage of -0.56% of the GDP between 2011 and 2016, accumulated at -0.69% by 2025. The effect of the loss of productive efficiency is more perverse on the country's economic activity (-0.45%), representing almost 65% of the total negative effect in the long-term. The trajectory of deviations generated on household consumption is similar to that of the GDP, since negative changes in aggregate real income would affect household consumption according to the proportion of this expenditure component. By 2025, the negative deviation on the growth rate of household consumption would total 0.75%. As households maximize their utility by expanding their consumption basket, a policy of cutting public funding with the adverse TFP effect generates a decrease in welfare (Table 4). The negative deviation in the utility of households was, on average, 1.42% below the baseline forecast path in 2025. As the productive activities no longer obtain the TFP gain related to R&D investments from public financing, unitary production costs expand and, consequently, there is an upward pressure on the economy's domestic prices, affecting both external and internal markets in the long-term. The trade balance registers a marginal reduction of 0.72% due to the TPF effect. According to the contribution of each market to expenditure-side real GDP, the expansion of the external market resulting from the absence of public R&D funding is lower than the negative effect generated by productive inefficiency, resulting in a total deviation of -0.02% in the long term (2025). The negative impact on the internal absorption components of output is softened by the growth of the external demand. The export volume grows because of the decline of the GDP deflator over the years.

Table 4 - Macroeconomic effects

Variáveis	Without public funding		TFP effect		Total	
	2011-2016	2011-2025	2011-2016	2011-2025	2011-2016	2011-2025
GDP (expenditure-side)	-0.18	-0.24	-0.38	-0.45	-0.56	-0.69
Intern market	-0.43	-0.34	-0.36	-0.34	-0.80	-0.68
External market	0.25	0.09	-0.02	-0.11	0.23	-0.02
Investment	-1.33	-0.80	-0.82	-0.44	-2.15	-1.24
R&D	-7.53	-6.50	-0.22	-0.18	-7.75	-6.67
Physical	-0.99	-0.40	-0.85	-0.45	-1.85	-0.86
Household demand	-0.37	-0.34	-0.35	-0.41	-0.72	-0.75
Exports	1.14	0.19	-0.42	-0.81	0.72	-0.62
Imports	-0.95	-0.28	-0.21	-0.09	-1.16	-0.38
Trade balance	2.09	0.47	-0.21	-0.72	1.88	-0.25
Employment	-0.09	0.02	-0.08	0.00	-0.17	0.02
Real wage	-0.45	-0.64	-0.19	-0.45	-0.63	-1.09
Capital stock	-0.20	-0.47	-0.12	-0.36	-0.33	-0.83
Knowledge	-4.75	-3.62	-0.07	-0.17	-4.81	-3.79
Physical	-0.18	-0.45	-0.12	-0.36	-0.30	-0.81
GDP deflator	-1.53	-0.20	0.33	0.82	-1.20	0.62
Wage	-1.79	-0.75	0.11	0.32	-1.68	-0.43
Rental capital	-1.41	0.24	-0.01	0.81	-1.43	1.05
Terms of trade	-1.08	-0.08	0.42	0.78	-0.66	0.69

Source: Research results.
Note: * % cumulative deviations from baseline.

Figure 5 – Selected path



Source: Research results.

By the competitiveness-cost approach, external demand is negatively related to the behavior of domestic prices and, therefore, generalized cost reductions stimulate a growth rate of exports above the baseline forecast path. Moreover, given the production complementarity and the possibility of imperfect substitutability between domestic goods and the imported equivalent, negative deviations from domestic prices would reduce the volume of imports, with an accumulated deviation of about -0.28% in 2025. Hence, the trade balance presents a negative deviation by 2025, but the terms of trade decline. These results suggest that the difference in the effects of exports and imports generate savings in the economy due to the need to adjust the marginal surplus in the trade balance. The terms of trade, defined by the difference in prices of exported and imported goods, have negative effects, reproducing the decrease in domestic prices and costs in the Brazilian economy. Since the physical and the knowledge capital stocks present a lagged movement from one year to another in relation to current investments, the adjustment of the sectoral production occurs mainly by the labor market, whereas the labor factor is mobile intersectorally and its supply is relatively more elastic. Thus, GDP decline in both policy simulations is associated with an aggregate employment below employment trends in the short-term, negatively affecting the real wage in the following period. On the other hand, according to mechanisms of a lagged adjustment process in the labor market, the initial employment growth negatively reaches the real wage in the subsequent years. The reduction of the real wage rates, which represents a cost decrease for each produced unit, stimulates the aggregate employment. At the end of this process of lagging adjustment between real wage and the national employment supply, national employment practically converges to the economy's employment trend in 2025. This time path occurs both in the absence of public financing and in the TFP effects (Table 4).

During the period covered by the policy simulations, the decrease in economic activity generates shrinkage in the capital demand of the economic system. This creates a downward pressure on capital rentals due to the imperfect substitutability among the primary factors and by the explicit relations of one-year gestation lag between the capital accumulation functions and the allocation of investments, which is guided by rates of return. Then, in both experiments, the reduction of capital rentals and asset prices negatively affects investors' current and expected return rates, discouraging the volume invested for subsequent years. Nevertheless, to the extent that capital depletes in the following years, the drop in the supply of physical and knowledge capital to a given production requirement gradually increases, which causes capital rentals and the expected rates of return and investment in each subsequent year to decrease as well. The volume of investments reacts positively to an outdated move, which would contribute to capital accumulation. Following this process, there is a continuous cooling of the negative changes in investments and capital until 2025. The inflection of the declining trajectory of investments and capital occurs shortly after the period of simulated policies. For example, the trajectory of the knowledge stock is inflected in 2018, one year after the very inflection of R&D investment. Given the theoretical specification of capital and investments, a slight resumption of economic activity occurs mainly through the hiring of additional labor in 2017. In the long-term, cutting public R&D investment funding and the related productivity loss lead to knowledge stock deviations below the baseline forecast path (around -3.79%).

However, the negative effects indirectly influence physical investment itself, because the reduction of production requirements in the R&D-producing sectors cause physical capital rental to decrease, lowering the volume of physical investments in the years when the policy is implemented. In general, capital-intensive activities face larger declines in their output and expected rate of return (Table 4 and Figure 5, Panel b). Medium-high and high technology-intensive industries are the ones that would most shrink in the long run without public funding and with the loss of productive efficiency (Table 5). By definition, they are sectors that are intensive in physical and knowledge capital, that absorb the largest shares of public funding and are the most important in the country's technological base. Together, these two types of industries accounted for 15% of total R&D investment and 34% of private R&D in the country during the period analyzed (see Table 2). Knowledge capital stock contracts by more than 20% in relation to the baseline until 2025. Given the capital-accumulation method, this cumulative fall of the knowledge capital is traced by the declining time path of private R&D investments (Table 5).

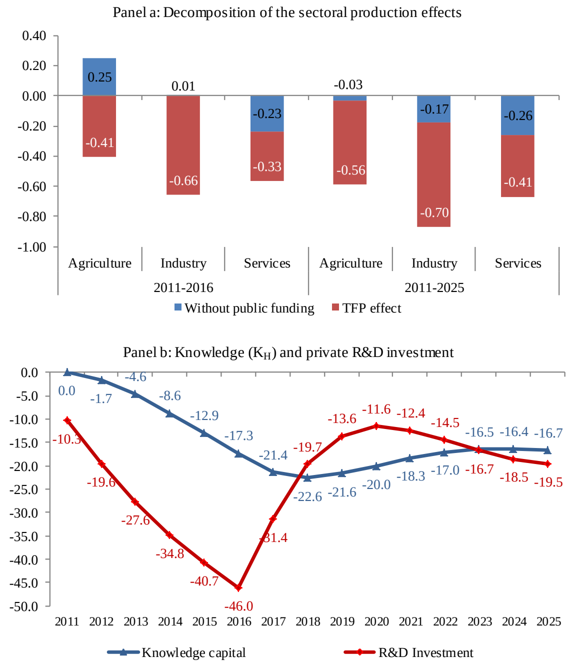
In addition, Figure 7 reports the main sectoral activities which are intensive in R&D and suggests that sectors such as Automobiles, trucks and buses, Machinery and mechanical equipment, Parts and accessories for vehicles, Other transportation equipment and Chemicals in general are those with medium-high and high technological intensity that present the highest losses in knowledge capital stock. The internal and external sales of these economic activities would accompany this negative trend. In general, R&D-intensive industries and KIBS, both dependent on public financing, are those with the largest declines in output, investment, and capital stock, including physical capital. The greater part of these negative effects is caused by TFP loss. The agricultural sector benefited from the deflationary effect of costs caused by the public financing cut policy, but only in the short term. Thus, disregarding the adverse TFP effect, the absence of public financing, by penalizing industrial and service activities, could promote some movement of economic primarization and specialization in the short term. By 2025, the downturn in domestic and external markets negatively affects all activity sectors in the country, even those that are labor-intensive (Figure 6, Panel a).

Table 5 - Effects on sectoral activities up to 2025

Figure 6 - Selected indicators *

Sectors	Output	Cumulative% deviation: Investment R&D	Investment hysical	Capital K_H	Capital K_F	Composition (%): Baseline K_H	Baseline R&D Inv.	Post-policies K_H	Post-policies R&D Inv.
Agriculture	-0.59	-	-0.81	-	-0.67	0.00	0.00	0.00	0.00
Industry	-0.87	-22.43	-0.66	-19.76	-0.29	32.19	36.01	27.33	30.47
Low	-0.72	-26.17	-0.11	-24.70	0.09	2.09	2.25	1.65	1.78
Average Low	-0.89	-12.95	-1.22	-12.20	-0.74	11.74	11.98	10.99	11.26
Average High	-1.00	-27.10	-0.18	-22.67	0.40	14.90	17.53	11.82	13.95
High	-0.87	-25.82	1.14	-20.55	0.35	3.46	4.25	2.87	3.47
Services	-0.67	2.20	-0.87	2.66	-0.96	67.81	63.99	72.67	69.53
KIBS	-1.02	-17.61	-0.87	-13.08	-0.64	12.53	14.13	11.35	12.28
Other services	-0.78	0.95	-0.83	-0.75	-0.99	3.51	3.92	3.70	4.22
Public administr.	-0.11	8.78	-2.04	4.87	-0.63	51.77	45.95	57.62	53.02
% GDP						4.20	0.68	3.55	0.57

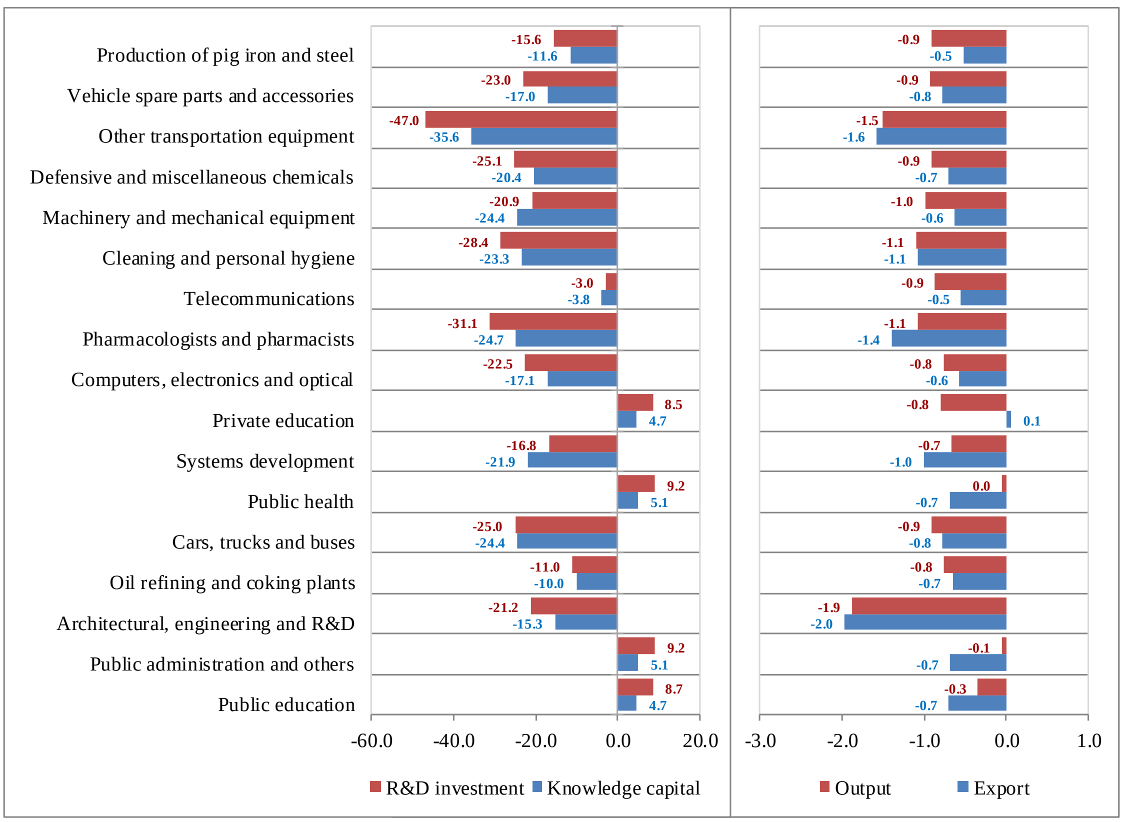
Source: Research results.



Source: Research results.

Nota: * % cumulative deviations from baseline.

Figure 7 - Effects on the main R&D-intensive sectors (2025)



Source: Research results.

Note: % cumulative deviations from baseline; The sectors selected represent 90% of total R&D investments in Brazil.

Due to declining in demand and the increase in unit production costs, R&D production in the Brazilian economy decreases by about 6.3% in 2025, despite the growth of public R&D in the period. Consequently, the R&D intensity rate (% GDP) in the Brazilian economy reduces by almost 0.11 p.p. in relation to the baseline forecast path, from 0.68% to 0.57%. The industry loses its share in the sectoral composition of knowledge capital and R&D investment, with a drop of 5 p.p. and 6 p.p., respectively. Investments and public R&D production increase due to the lowering of the primary factors in private production costs, allowing additional units of knowledge capital creation – a cumulative deviation of around 4.87% in 2025 (Table 5 and Figure 6, Panel b). Therefore, policy simulations suggest that the lack of public financing in private R&D investment makes the public sector even more responsible for producing the country's technological base in a scenario of declining R&D intensity. Public education is one of the main sources of expansion of knowledge stock (with an accumulated deviation of 4.7%), although the Brazilian economy is less intensive in R&D (Figure 7). These results corroborate the assertions of Pellens et al. (2018), who point out which economic downturns would systematically modify the composition of public R&D spending, leading to a countercyclical strategy of the private sectors with the highest technological intensity.

5 Concluding Remarks

This paper offers contributions on the role of public financing in private R&D investments, evaluating what would be the main economic effects if this form of public policy were inexistent in the Brazilian economy. Given that the benchmark scenario of the Brazilian economy had already been observed, we sought to fully withdraw the R&D funding amounts and to assess deviations from the main macroeconomic indicators and the main sectoral groups. R&D investments promote productivity gains of the primary factors. In this sense, the absence of public financing policies also implies TFP loss in the productive system. Thus, the research proceeded from the development of an empirical strategy of integration of a two-stage econometric model, which estimated the TFP elasticity in relation to R&D investments, alongside a dynamic general equilibrium model that incorporate applied elements within its theoretical structure, such as different forms of sectoral allocation of investments and the flow-stock relationship between knowledge capital and R&D investment. This CGE model allowed us to consider direct and indirect channels for the production and consumption links established with knowledge capital, R&D investment and changes in TFP, whose elements treat the performance of the economy better than standard CGE models

The main findings show that the cutback in public financing policies and the loss of productive efficiency would cause the country to be less R&D intensive, and the public sector to be even more responsible for and pressured into producing the country's knowledge stock. The role of public education in this regard would be even greater in promoting R&D in Brazil in the face of a possible cut of funding in the public budget. In addition, the cutback in public investment to private R&D spending would also generate indirect and adverse effects on the formation of physical capital, in view of the loss of return on capital and investments between 2011 and 2025. There would be, in general, a decrease in the GDP (for domestic and external markets) and in the level of activity of the industrial sectors of high and medium-high technological intensity, the very ones which depend on public R&D the most. This scenario of reduction of the country's technological base would counteract the tendency of the main economies in the world, which seek to increase their R&D intensity in a context of rapid internationalization and fragmentation of production processes around the world.

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