Industrialization and deindustrialization: an empirical analysis of some drivers of structural change in Brazil, 1947-2021

Industrialização e desindustrialização: uma análise empírica das causas de mudança estrutural no Brasil, 1947-2021

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RESUMO: Este artigo investiga as causas da mudança estrutural no Brasil, a ascensão e a queda da indústria manufatureira, e as consequências disso para a produtividade total dos fatores e a produtividade do trabalho das atividades manufatureiras, de 1947 a 2021. Nossos resultados mostram que a industrialização da estrutura produtiva brasileira está positivamente associada à expansão dos investimentos em infraestrutura e à busca de uma taxa de câmbio real competitiva, ou seja, a políticas orientadas para o desenvolvimento econômico. Nossos resultados também indicam que essas variáveis exercem influência direta na produtividade total dos fatores e na produtividade do trabalho industrial, e influência indireta por meio de seus impactos na estrutura produtiva brasileira. Nossas conclusões sugerem que uma causa importante da desindustrialização prematura brasileira, e de seu fraco desempenho em termos de produtividade total dos fatores e produtividade do trabalho industrial, é a adoção de políticas não orientadas para o desenvolvimento econômico adotadas desde as reformas neoliberais das décadas de 1980 e 1990.
PALAVRAS-CHAVE: Mudança estrutural; produtividade do trabalho; infraestrutura; taxa de câmbio real; Brasil.

ABSTRACT: This article investigates the causes of structural change in Brazil, through the rise and the fall of the manufacturing industry, and the consequences for total factor productivity and manufacturing labour productivity, from 1947 to 2021. Our results show that the industrialization of the Brazilian productive structure is positively associated with expansions in infrastructure investments and with the pursuit of a competitive real exchange rate, that is, with policies oriented towards economic development. Our findings also indicate that such variables exert a direct influence on total factor productivity and manufacturing labour

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productivity and an indirect influence through their impacts on the Brazilian productive structure. Our conclusions suggest that an important cause of the Brazilian premature deindustrialization, and then of its poor performance in terms of total factor productivity and manufacturing labour productivity, is the adoption of policies not oriented towards economic development adopted since the neoliberal reforms of the 1980s and 1990s.
KEYWORDS: Structural change; labour productivity; infrastructure; real exchange rate; Brazil.
JEL Classification: O1; O11; O14.

1. INTRODUCTION

Economic development is a process of a structural change in the sectoral composition of gross domestic product (Ocampo et al., 2009), which is connected to changes in population, technological progress, and patterns of consumption. All these factors have consequences for production, employment, and prices (Pasinetti, 1981). In richer countries, most of the population is employed in modern, high-productivity, and more complex sectors, such as manufacturing and high-tech sectors. As there is a positive correlation between long-term growth and the composition of the productive structure, industrialized economies are more prosperous (Kaldor, 1966; Atolia et al., 2020). From a macroeconomic perspective, the active promotion of structural change – meaning the transfer of resources from agriculture and low-productivity services towards the more high-productivity manufacturing sectors, (in line with Lewis (1954)) and the policies associated with such a purpose – is the fundamental driver of economic growth (Rodrik, 2013).

In this context, many scholars have been emphasizing that normal deindustrialization – in terms of manufacturing employment, occurs as countries' income per capita increases (e.g., Rowthorn and J. Wells, 1987; Rowthorn & Ramaswamy, 1999; Rowthorn and Wells, 1987; Palma, 2005; Tregenna, 2016; Rodrik, 2016; among many others). Premature deindustrialization occurs in countries at lower levels of income per capita than the international standard (Tregenna, 2016). A possible explanation for this is the adoption of neoliberal policies associated with trade and financial liberalization, liberal reforms, and austere monetary and fiscal policies (Palma, 2005; Tregenna, 2016), like the policies implemented in Brazil after the radical neoliberal reforms implemented over the 1980s and 1990s after a long period of state-led industrialization since the 1950s (Palma, 2005; Andreoni and Tregenna, 2020). Premature deindustrialization damages the possibilities of economic development and accumulation of technological capabilities, undermining the ability to obtain gains of productivity growth (Andreoni and Tregenna, 2020).

Applying this logic to Brazil, it is clear that the Brazilian economy is currently moving in the opposite direction of a solid, long-term growth path. Indeed, since the mid-1980s, the country's productive structure has been undergoing an intensive and premature process of deindustrialization, with adverse effects on labour productivity and the total factor productivity (TFP). This has come after a long period of development-oriented policies associated with the promotion of industrialization, beginning in the 1950s (Nassif et al., 2015; Oreiro, et al., 2018; Morceiro and Guilhoto, 2023).

In this article, in line with the argument of Palma (2005) and Tregenna (2016), we argue that part of premature Brazilian industrialization has arisen from the economic policies governing public investment in infrastructure and the real exchange rate (RER) – that is, from a change from policies oriented to economic development towards policies associated with fiscal consolidation (which leads to reduced infrastructure investments) and inflationary control via the pursuit of an overvalued RER – neoliberal policies. In other words, the structural change that Brazil has experienced over the last seven decades – industrialization and deindustrialization – is linked to the economic policies of the State in terms of public investment, infrastructure investments, and the conduct of RER policy, or, in the case of its premature deindustrialization, it is linked to changes in economic policies from an institutional regime based on the state-led industrialization towards neoliberal economic and political reforms (Palma, 2005; Tregenna, 2016).

With this in mind, we argue that development policies conducted by State are crucial to diversifying and industrializing productive structure, either because via the promotion of new investments in infrastructure, or via the pursuit of a competitive RER. In this regard, both the empirical and theoretical literature point to the importance of an active policy regarding investment in infrastructure, as well as the conduct of the RER for boosting long-term performance. There are many channels of transmission through which both these variables may influence economic growth. Investment in infrastructure directly affects short-term output as many growth models consider it an additional variable in the production function (Barro, 1990; Välilä, 2020). Infrastructure has an indirect effect on long-term growth through its influence of the marginal productivity of capital by inducing efficiency gains through the international market – insofar as better infrastructure reduces the unit costs of production (Barro, 1990; Bogetic and Fedderke, 2005; Agénor and Moreno-Dodson, 2006; Välilä, 2020). Regarding the second variable, a competitive RER is associated with the composition of the productive structure and with long-term growth, as it influences the profitability of tradable sectors that make up the manufacturing industry (Rodrik, 2008; Bahlla, 2012; Oreiro et al. 2020; Marconi et al., 2021). A competitive RER is associated with the manufacturing industry's capital accumulation and technological progress, with reverberating effects on labour productivity, TFP, and economic growth (Bahmani-Oskooe and Hajilee, 2010; Mbaye, 2013; Rapetti, 2020; Demir and Ramzi, 2021).

Considering this, the study aims to investigate the macroeconomic causes of structural change in Brazil and its consequences for TFP and manufacturing labour productivity in the period 1947-2021. To do this, time series regressions were carried out using the Autoregressive Distributed Lag (ARDL) cointegration analysis and the ARDL bounds-testing approach developed by Pesaran and Shin (1999) and Pesaran et al. (2001). Our findings show that infrastructure, increased public investments, and a competitive RER are positively associated with periods of industrialization, gains in TFP and manufacturing labour productivity. At the same time, our estimates show a positive and indirect effect of these variables on TFP through its industrializing effects on the productive structure.

We contribute to the existing literature on the causes of structural change in Brazil in a number of ways. First, we combine a range of data sources covering more than 70 years, which, for the first time, has allowed an econometric evaluation of the intense periods of industrialization (from the 1950s to the mid-1980s) and deindustrialization (from the mid-1980s to 2021). To the best of our knowledge, this study is pioneering in that it provides long-term empirical evidence that public investment and infrastructure (measured by different variables) are associated with structural change within the Brazilian productive structure – besides the usual variables considered by the literature, such as the RER. Furthermore, our study is pioneering in that it demonstrates the direct effects of these variables on TFP and manufacturing labour productivity, as well as its indirect effects through its influence on changes in the productive structure. Indeed, we believe that our study may help in the design of an appropriate policy for the reindustrialization of Brazil and other developing countries suffering from premature deindustrialization.

The rest of the paper is structured as follows. The second section provides the conceptual framework for discussing the literature on the importance of structural change for economic growth and the role played by investment in infrastructure and RER in promoting economic growth. The third section presents an overview of structural change in Brazil from a historical perspective. The fourth section discusses the empirical strategy adopted in our econometric regressions. The fifth section presents and discusses our empirical findings. The last section offers some concluding thoughts.

2. CONCEPTUAL FRAMEWORK

In this section, we briefly show how structural change towards high-productivity manufacturing plays a critical role in economic growth and the channels through which investments in infrastructure and the RER influence economic growth.

2.1 Structural change toward industrialization

The concept of structural change towards manufacturing as being an engine of long-term growth (Kaldor, 1966; Ocampo, 2005; Atolia et al., 2020) is widely known as Kaldor's first law. There is ample literature to support it (e.g., Szirmai, 2012; Ros, 2015; Marconi et al., 2016; Weiss and Jalilian, 2015; Cantore et al. 2017; Haraguchi et al., 2017). As Rodrik notes, "Our modern world is in many ways the product of industrialization" (Rodrik, 2016, p. 1). The development of manufacturing sectors, or industrialization, is thus positively associated with long-term growth. Indeed, industrialization induces strong backward and forward sectoral linkages that stimulate aggregate demand (Hirschman, 1958; Tregenna, Andreoni, 2020) and it increases the potential for externalities across the whole economy (Weiss and Jalilian, 2015). The manufacturing industry has the specific capacity to drive technological progress, faster capital accumulation, and growth in labour productivity (Szirmai, 2012; Tregenna and Andreoni, 2020). Manufacturing activities bring about increasing returns of scale because higher growth in demand is positively associated with growth in labour productivity growth (Kaldor, 1966). As manufacturing activities absorb the resources used (mainly labour) in traditional sectors, both labour productivity and real wages across the whole economy increase (Lewis, 1954; Kaldor, 1966; Ros, 2015). As a tradable activity, manufacturing offers huge potential for gains through international trade (Weiss and Jalilian, 2015; Rodrik, 2016). International trade relaxes restrictions on the balance of payments (Thirlwall, 2002) and by contributing to the trade balance, manufacturing allows countries to manage their macroeconomic policies with greater autonomy. The manufacturing sector also has the capacity to promote regional development as regions that host industrial plants undergo major transformation (Moretti, 2010). The development of manufacturing is also associated with the creation of more formal and better-paid employment and a higher contribution of human capital and institutions to economic growth (Su and Yao, 2016).

2.2 The role of infrastructure and the real exchange rate in economic growth

In development economics literature, there is general consensus that investment in infrastructure and the RER influence the economic development process or long-term growth. There are many reasons why augmented infrastructure investments and/or a competitive RER impact economic growth.

The link between public and infrastructure investments and economic growth began to gain traction with Keynes (1936). Since then, many growth models have been incorporating public investment in infrastructure within their framework for assessing the determinants of economic growth. In the empirical literature, which also shows considerable analytical heterogeneity, the pioneering studies of Mera (1973) and Ratner (1983) indicated a positive effect of public investment on output. However, it was the breakthrough contribution of Aschauer (1989) that empirically demonstrated the strategic role played by public investment in determining the total factor productivity (TFP) in the US economy. Specifically, Aschauer's analysis showed the positive link between public capital (stock and flow) and productivity – and this link became a frequent reference point in growth studies. In a later study, Aschauer (1998) provided evidence showing that public investment was positively associated with the long-term growth of 46 developing countries between 1970 and 1990. This underlined the importance of the reallocation of government consumption towards public investment as a reliable source of financing for the expansion of public investment.

Numerous studies have confirmed the importance of investment in infrastructure for expanding output (e.g., Esfahani and Ramirez, 2002; Straub, 2008; Égert, et al., 2009). There is extensive literature on the influence of public investment on output across a range of countries. The literature covers diverse uses of data, methods, and samples (Straub; 2008, Bom and Ligthart, 2014; Välilä, 2020). For example, focusing on studies that employed the Cobb-Douglas production function model, Bom and Ligthart (2014) analysed 578 estimates of the output elasticity of public capital from the existing literature to synthesize their results. The survey provided by the authors indicated an average output elasticity concerning public capital of around 0.10.

In the theoretical literature, investment in infrastructure has been increasingly considered an essential driver of long-term growth. Much of the literature indicates various transmission channels, such as direct and indirect effects, from changes in infrastructure capital to economic growth. Public and infrastructure investments increase labour productivity as well as the private capital stock used in a typical Cobb-Douglas function of neoclassical growth models (Barro, 1990; Agénor and Moreno-Dodson, 2006; Välilä, 2020). In line with this endogenous growth approach, infrastructure investments are associated with greater total factor productivity (Barro, 1990; Välilä, 2020). Moreover, public capital favours private decisions to make new investments, insofar as infrastructure improvements reduce unit production costs and expand the marginal productivity of private capital (Agénor and Moreno-Dodson, 2006; Välilä, 2020). Furthermore, there is a complementary effect on private investment as the reduced unit costs, combined with greater marginal productivity of capital, boost the rate of return of private sectors, thus inducing more production and investments (Bogetic and Fedderke, 2005; Agénor and Moreno-Dodson, 2006). There is an additional positive effect on innovative pressures stemming from national production entering international markets (Bogetic and Fedderke, 2005; Välilä, 2020). Investments in infrastructure may also induce greater labour productivity because they improve workers' access to roads, public transportation, electricity, and telecommunications – all leading to enhanced economic growth and poverty alleviation (Agénor and Moreno-Dodson, 2006; Straub, 2008). At the same time, the greater the spending of public capital, the more durable private capital is (Agénor and Moreno-Dodson, 2006; Straub, 2008).

On the other hand, there is a well-established body of empirical literature on the positive effects of a competitive RER on economic growth (e.g., Rodrik, 2008; Bahlla, 2012; Gabriel et al., 2020; Rapetti, 2020; Ramzi, 2021). In the theoretical literature, there are many transmission channels through which the RER affects economic growth. The profitability channel indicates that a competitive RER expands the profitability of tradable sectors as it lowers labour costs and increases export revenues (Bahlla, 2012). Further, there is the distributive effect as a competitive RER transfers income from workers/real wages (class with a low propensity to save) to firms/profits (class with greater propensity to save) (Glüzmann et al., 2012; Guzman et al., 2018). Consequently, a competitive RER leads to an investment effect as firms tend to increase investment (as a result of the accumulated/augmented profits). In other words, a competitive RER instigates the capital accumulation of tradable activities at the expense of consumption. Importantly, this leads to the "structural change effect" insofar as it induces structural transformation by benefiting manufacturing sectors and diversifying the production structure (Rodrik, 2008; Missio et al., 2015; Oreiro et al., 2020; Marconi et al., 2021). In addition, there are reverberating effects on technological progress (Rodrik, 2008; Bahmani-Oskooe and Hajilee, 2010) and TFP (Mbaye, 2013). The development channel summarizes these effects: a competitive RER induces capital accumulation, the productivity of factors, the allocation of resources, and the productive structure – all of which favour economic growth (Rapetti, 2020; Demir and Ramzi, 2021).

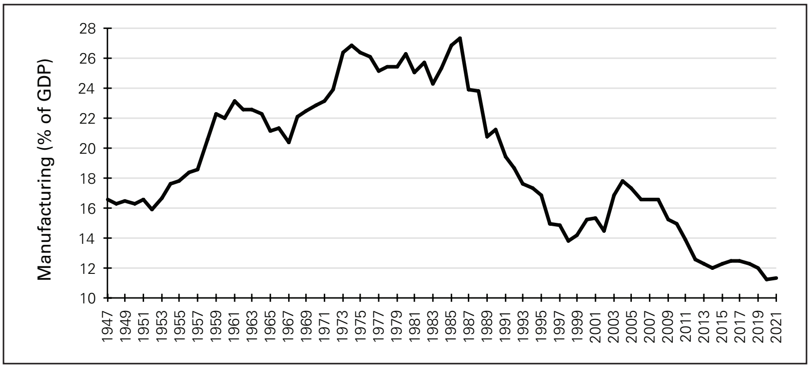
In sum, the conduct of government policy regarding investment in infrastructure and the maintenance of a competitive RER are essential parts of a consistent growth-enhancing strategy. Considering this discussion, the next section sheds light on the structural change – the development and decline of manufacturing – in Brazil from a historical perspective.

3. INDUSTRIALIZATION AND DEINDUSTRIALIZATION IN BRAZIL: A HISTORICAL PERSPECTIVE

Over the last seven decades, the Brazilian economy has shown two distinct trajectories of structural change (Morceiro and Guilhoto, 2023). First, from 1950 to the mid-1980s, the country underwent a significant phase of industrialization, showing robust GDP growth averaging almost three percentage points higher than that of the world economy. On the other hand, later, in the period spanning the mid-1980s to 2021, Brazil underwent a phase of premature deindustrialization, with weak GDP growth averaging one percentage point lower than that of the world economy. It is important to note that public and infrastructure investments and exchange rate policy played crucial roles in these two distinct trajectories.

Figures 1, 2 and 3 show historical data for the periods of industrialization and deindustrialization. It is clear that in the 30 odd years until about 1980, industrialization (Figure 1), public and infrastructure investments (Figure 2) and productivity (Figure 3) advanced substantially.

Figure 1: Brazil manufacturing sector (% of GDP) 1947-2021



Source: Morceiro (2021).

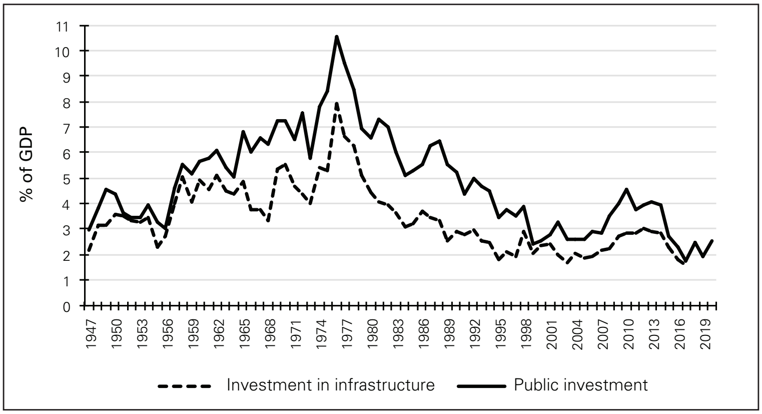
In this first phase, in which the State actively guided the industrialization process (Suzigan, 1988), the manufacturing share of GDP increased from 16.3% to 27.3% (Figure 1). This phase is characterized by rigorous planning on the part of the State, which implemented several development programs, such as the Goals Plan (1956-1961), the Government Economic Action Program (1964-1967), and the II National Development Plan (1975-1979). The Brazilian State also promoted a strongly protected industrialization process that included several classic industrial policy instruments, such as local content requirements, high import tariffs, and subsidized interest rates (Suzigan, 1988, 1996). Public infrastructure projects (Figure 2), such as the Transamazon Highway (BR-230) and the Itaipu hydroelectric plant, were critical for expanding the logistics and energy network, as well as accelerating the industrialization of industrial sub-sectors that were direct beneficiaries of the schemes, such as capital goods and non-metallic minerals. The State also acted as an entrepreneur by creating and expanding State companies in critical areas such as petroleum, electric energy, mining, steel, metallurgy, chemicals, telecommunications, and aviation (Castro, 1985; Suzigan, 1988). By expanding demand through public investments, state-owned companies played a strategic role in accelerating GDP growth.

The RER also played an important role in industrialization and the exporting of manufactured goods during this period. A competitive RER at various points, such as during the Goals Plan and in the early 1980s, was another crucial instrument for industrialization and the exporting of manufactured goods of the Brazilian economy (Nassif et al., 2020).

All these plans, measures, and actions on the part of the State resulted in the enlargement and diversification of the industrial arena. Particularly notable was the establishment of the industries in durable consumer goods, intermediate goods, and capital goods – all sectors most challenging to be internalized at the time (Morceiro and Guilhoto, 2023). So, by the mid-1980s, Brazil had an integrated, comprehensive, and diversified industrial sector (Castro, 1985). However, the country did not produce industrial goods efficiently because the domestic industry was overly protected (Suzigan, 1996), as well as being characterized by poor technological development (Baer, 1985) and a low export coefficient (Suzigan, 1988). Nevertheless, the strong growth in manufacturing labour productivity and TFP was clearly a result of robust structural transformation (Figure 3), which served to narrow the productivity gap with advanced countries (Nassif and Morceiro, 2022).

However, a change was to come in the 1980s. Due to the difficulty in obtaining foreign exchange to pay foreign debt, as well as the loss of control of inflation, the state-oriented industrialization model experienced a crisis. This brought about changes in the development model in the late 1980s and early 1990s, including the 1988 Constitution, more open trade and finance systems, large-scale privatizations, and the Real Plan, which stabilized inflation. The previous priority of public investments in infrastructure shifted to an emphasis on more social spending, such as on health and education – substantially reducing public investments in infrastructure as a proportion of GDP (Figure 2).

Figure 2: Brazil: Public and infrastructure investments (% of GDP) 1947-2020



Note: Public investment also includes investment by state-owned enterprises.
Source: Pires (2022) and Júnior and Cornelio (2020).

As Figure 2 shows, public investment as a share of GDP has decreased substantially, as the many state-owned companies that used to make investments in strategic areas have been privatized. Pro-industry policies became increasingly rare. Since 1994, macroeconomic policy has favoured high interest rates and an increased exchange rate as a means of controlling inflation. This more recent approach at the macroeconomic level and accompanying State actions have not been beneficial for growth-based structural change. Due to the significant adjustments to the development model, between 1986 and 1998 manufacturing's share of GDP halved – from 27.3% to 13.8% (Figure 1). This process of deindustrialization continued into the 21st century, falling to its lowest level in 2019-2021 (Figure 1). In this sense, many authors have stressed the role played by the adoption of a valued RER, mainly after the Real Plan in 1994 when the RER was used as a nominal anchor, to explain the Brazilian deindustrialization (e.g., Bresser-Pereira, 2010; Oreiro and Feijó, 2010; Oreiro et al., 2018; Nassif et al., 2020; Bresser-Pereira, 2022).

Figure 3: Brazil: Productivity measures at constant prices: 1950-2019

Source: See Table 1 in section 3.

It can be safely concluded that Brazilian's deindustrialization has been premature (Palma, 2005; Nassif and Morceiro, 2022). Indeed, the country began to deindustrialize intensively with a very low GDP per capita, about half the standard found by the literature (Palma, 2005; Rodrik, 2016; Felipe et al., 2019). The weak dynamics and stagnation of manufacturing labour productivity and TFP since the mid-1980s (Figure 3) provides further evidence of premature deindustrialization, compared to deindustrialization in advanced countries. Brazil has not surpassed the income level that would allow it to escape the middle-income trap, and it has not been able to grow through expanding more sophisticated services that pay higher wages (Nassif and Morceiro, 2022). The change of course from industrialization to deindustrialization has contributed to reinforce the reliance on natural and primary resources while low-productivity informal services have expanded. The result is the entrenching of a deep structural duality that is typical of developing countries in the Global South (Nassif and Morceiro, 2022).

While there is much theoretical evidence on the range of factors causing industrialization and deindustrialization, to date no empirical study has investigated these factors over lengthy periods. This paper aims to address this gap. Its ability to do this has been made possible by the recent availability of long historical series for the main variables – covered in the next section.

4. EMPIRICAL PROCEDURES

This section introduces the database and the empirical strategy used in our empirical estimates.

4.1 Database

In order to understand the influence of development policies on the Brazilian productive structure, the empirical strategy consists of estimating a set of time-series regressions. The four dependent variables in our regressions are: i) manufacturing GDP as a share of total GDP (Industry); ii) employment in the manufacturing sector (Employment); iii) total factor productivity (TFP); and iv) the labour productivity of the manufacturing sector (Productivity). Table 1, below, gives more details on these variables, like their definitions, the time span, and data sources. It is important to note that our variables are covered across different periods. We endeavoured to maximize the years contained in our sample.

Table 1: Variables

Variable	Definition and sample	Source
Industry	Manufacturing GDP as a share of total GDP (1947–2021)	Morceiro (2021)
Employment	Employment in the manufacturing sector (1950–2019)	Authors' calculations of the annual rate of change in manufacturing employment from various. Sources of annual variation for each period are: 1950–1976 (Timmer, De Vries, & De Vries, 2016), 1977–1990 (IBGE1, 2006), 1991–2000 (IBGE, 2004) and 2001–2019 (IBGE, 2021)
TFP	Total Factor Productivity (1954-2019)	Penn World Table 10.0
Productivity	Manufacturing labour productivity (1950–2019)	Authors' calculations using IBGE national accounts data for the value-added variable. See above the for the employment variable.
RER	Real exchange rate (1960–2020)	Darvas (2021)
Infrastructure a	Gross fixed capital formation (GFCF) in infrastructure (1947–2017)	Júnior and Cornelio (2020)
Infrastructure b	Public investment as a share of GDP (1947–2020)	Pires (2022)
Infrastructure c	Investment in construction as a share of GDP (1947–2020)	Júnior and Cornelio (2020)
K/L	Ratio of investment in machinery and manufacturing employment (1950–2017)	Júnior and Cornelio (2020) for the investment in machinery variable. See above the for employment variable.
Infl	Inflation rate (1947–2021)	Institute of Applied Economic Research (IPEA)
TOT	Terms of trade: the ratio of exports and imports prices (1947–2021)	Institute of Applied Economic Research (IPEA)

Source: Authors.
Notes: 1 Brazilian Institute of Geography and Statistics.

We estimated a log-linear functional specification to explain our dependent variables. Below are the equations of interest in this article for explaining the structural composition of the Brazilian economy – represented by the two variables of Industry and Employment.

$$Industry_t = c + b_1RER + b_2Infra + b_3K/L + b_4Infl + b_5Productivity + b_6TOT + \varepsilon_t \quad (1)$$

$$Employment_t = c + b_1RER + b_2Infrastructure + b_3K/L + b_4Infl + b_5TOT + \varepsilon_t \quad (2)$$

Below are the log-linear functional specifications to explain the two variables of TFP and manufacturing labour productivity .

$$\text{TFP}_t = c + b_1\text{RER} + b_2\text{Infrastructure} + b_3\text{K/L} + b_4\text{Industry} + \varepsilon_t \quad (3)$$

$$\text{Productivity}_t = c + b_1\text{RER} + b_2\text{Infrastructure} + b_3\text{K/L} + b_4\text{Industry} + \varepsilon_t \quad (4)$$

The parameter *c* is a constant term. The RER variable was introduced in our estimates to show how a competitive RER induces the industrialization of the economy (Rodrik, 2008; Ros, 2015; Oreiro et al., 2020; Iasco-Pereira and Missio, 2022), with possible reverberating effects on TFP and manufacturing labour productivity (Mbaye, 2012). We take the logarithm of its original values (divided by 100). Negative (positive) values represent a devalued (valued) RER in relation to the year base. Therefore, a negative parameter in estimates means that a competitive RER is positively associated with our dependent variable, and vice-versa.

We used three further variables to capture investment in infrastructure: The first is Infrastructure a, which stands for the gross fixed capital formation (GFCF) in infrastructure. The second, Infrastructure b, represents the public investment as a share of GDP. It is common in the literature to use public investment as a proxy for infrastructure investment, though it needs to be borne in mind that this excludes non-public investment in infrastructure, which limits the analysis (Välilä, 2020). The third variable, Infrastructure c, is the investment in construction as a share of GDP. These variables capture the flow of public investment in infrastructure from a macroeconomic perspective as it is usually covered in the literature (e.g., Aschauer, 1989, 1998; Straub, 2008, Välilä, 2020).

Haraguchi (2015) argues that the dynamic of industrialization is associated with different capital and technology intensities over time. From the early (light) labour-intensive industries (such as clothing apparel) to late (heavy) capital-intensive industries (such as motor vehicles and machinery), there is growing capital and technology intensity as the industrialization process advances (Haraguchi, 2015). To capture the Haraguchi's argument, we introduce the K/L variable in our regressions – that is, the ratio of investment in machinery to manufacturing employment. The inflation variable (Infl) captures macroeconomic stability. We argue that macroeconomic instability, which is represented by a high inflation rate, hinders the industrialization process, as well as gains in TFP and manufacturing labour productivity. The terms of trade (TOT) variable capture the argument of Bresser-Pereira (2016), according to which the highest TOT creates the phenomenon of Dutch Disease, which contributes to the deindustrialization of the economy.

4.2 Econometric method

Our regressions were performed using the Autoregressive Distributed Lag (ARDL) cointegration analysis and the ARDL bounds testing approach developed by Pesaran and Shin (1999) and Pesaran et al. (2001). This methodology has four main advantages regarding the cointegration methods of Engle and Granger (1987) and Johansen (1988): first, the ARDL approach is an appropriate method when variables are I(0), I(1), or a combination of I(0) and I(1) variables; second, the ARDL estimates are appropriated to investigate the long-term relationship for a small sample; third, variables are used in different lags, which improves the efficiency of estimates; and fourth, the short- and long-term relationships are estimated within a single equation, instead of a system of equations.

The appropriate number of lags was chosen according to the Akaike Information Criterion (AIC). We tested the existence of a long-term relationship using the bounds-testing procedure, which is a Test-F with a null hypothesis of no cointegration (H_0: $\delta = 0$) against the alternative of cointegration (H_1: $\delta \neq 0$). In the case of not accepting the null hypothesis (that is, there is a long-term relationship among our variables), the long-term multipliers are represented by estimated coefficients for the dependent variables in level. Short-term multipliers are the estimated coefficients for the dependent variables in the first difference. The estimated parameter for the speed of adjustment towards long-run equilibrium (error correction term) should be negative and statistically significant.

Our regressions were performed using different combinations of dependent variables. This has proven to be essential for checking the robustness of the results and to avoid possible collinearity. Moreover, not all combinations are associated with a cointegration relationship between our variables, which is required to obtain meaningful estimates. Thus, we only presented regressions that rejected the null hypothesis of the bounds-testing procedures.

The following section presents our empirical findings.

5. EMPIRICAL FINDINGS

This section discusses the empirical findings. All regressions were found to have fit well. The Breusch Pagan test has indicated a non-correlated error term. The bounds-testing procedure indicated a long-term relationship between our variables at least at 5% of critical values (at 1% for most regressions). The estimated parameter for the speed of adjustment towards equilibrium was negative and statistically significant in all regressions.

5.1 Structural change

Table 2 shows the regressions that were carried out to explain the manufacturing share of GDP (Industry). Regarding the long-term multipliers, our findings indicated the importance of RER, infrastructure investments, and capital accumulation per manufacturing worker to explain Brazil's deindustrialization/industrialization process sin – as only these variables were statistically significant. The estimated parameter for the RER variable was negative and statistically significant at 1% of critical values in all regressions. On the one hand, such a result indicates that a more competitive RER is associated with a structural change in the direction of manufacturing activities. On the other hand, a non-competitive RER is part of the explanation for the deindustrialization of the Brazilian economy.

Furthermore, the estimates suggest a positive parameter for the Infrastructure a[1] variable and the K/L variable. All this evidence suggests that infrastructure investments and capital deepening have positively affected the development of the manufacturing sectors within the Brazilian economy.

Regarding the short-term multipliers, our findings confirmed the positive association between a competitive RER, infrastructure investments, and the capital-labour ratio and industrial development.

Table 2: Structural change (dependent variable: Industry)

Model	(1)	(2)	(3)	(4)	(5)	(6)
Econometric tests						
Best model (Aic)	(2, 3, 0) -187.0	(1, 0, 2) -196.5	(1, 0, 0) -191.7	(1, 0, 1, 0) -186.7	(1, 0, 1, 0) -185.1	(1, 1, 1, 0, 2, 0, 0) -190.2
BG test (p-value)	0.46	0.33	0.26	0.64	0.97	0.62
Bound F-test (p-value)	F= 7.57 0.00	F= 8.31 0.00	F= 4.90 0.03	F= 5.87 0.00	F= 5.45 0.00	F= 4.46 0.00
Short-term multipliers						
RER	-0.72*** [0.18]	-1.06*** [0.29]	-1.40* [0.72]	-0.66*** [0.18]	-0.63*** [0.21]	-0.70** [0.30]
Infrastructure a	0.61*** [0.07]			0.45*** [0.10]	0.49*** [0.06]	0.29 [0.19]
K/L		1.25*** [0.20]				0.79* [0.43]
Inflation			-0.07 [0.06]			-0.02 [0.02]
Productivity				0.32 [0.23]		-0.03 [0.34]
TOT					-0.13 [0.16]	0.05 [0.28]
Long-term multipliers						
RER	-0.72*** [0.18]	-1.06*** [0.29]	-1.40* [0.72]	-0.66*** [0.18]	-0.63*** [0.21]	-0.70** [0.30]
Infrastructure a	0.29*** [0.07]			0.16 [0.16]	0.25*** [0.06]	0.05 [0.19]

[1] We have performed estimates using the variables Infrastructure b and/or Infrastructure c. However, the Bound F-test of these regressions did not fit well.

K/L		0.59*** [0.20]				0.46 [0.43]
Inflation			-0.07 [0.06]			-0.03 [0.02]
Productivity				0.32 [0.23]		-0.03 [0.34]
TOT					-0.13 [0.16]	-0.48 [0.28]
Speed of adjustment towards equilibrium						
Ect. (p-value)	-0.24*** [0.18]	-0.15*** [0.04]	-0.09*** [0.04]	-0.24*** [0.05]	-0.25*** [0.07]	-0.21*** [0.08]

Notes: a) standard errors are in brackets; b) regressions of Table 2 were performed with the introduction of a time trend; c) the intercept and trend parameters are not presented due to limited space, but are available upon request; d) *, ** and *** mean, respectively, statically significant at 10%, 5% and 1%; e) all regressions were performed using the option max lag (3) according to the Akaike information criterion (Aic).

Table 3 shows the regressions performed to explain our other measure of changes in production structure and employment in manufacturing activities (Employment). Its findings are in line with the results shown in Table 2. The estimated long-terms multipliers indicated the importance of RER and infrastructure investments to explain changes in employment in manufacturing activities. The estimated parameter for RER was statistically significant (at least at 5% of critical values) and negative in all regressions. Thus, a competitive RER is positively associated with manufacturing employment. In turn, the estimated parameter for the Infrastructure a variable is also positive and statistically significant, at 1% of critical values in all equations of Table 3. This shows that expansions in physical, social, and technological infrastructure may ignite the creation of jobs in manufacturing activities and vice-versa. To express this in a different way, economic policies associated with pursuing a competitive RER and greater values of investments in infrastructure unleash a structural change by transferring workers from non-industrial activities to the manufacturing sector, in line with the thinking of Lewis (1954).

Table 3: Structural change (dependent variable: employment in manufacturing activities)

Model	(1)	(2)	(3)	(4)	(5)
Econometric tests					
Best model (Aic)	(1, 1, 1) -211.5	(1, 1, 1, 0) -209.9	(1, 0, 1, 0) -211.2	(1, 0, 1, 0, 0) -209.5	(1, 1, 1, 0, 0, 2) -220.7
BG test (p-value)	0.41	0.21	0.86	0.39	0.45
Bound F-test (p-value)	F= 10.7 0.00	F= 8.01 0.00	F= 10.5 0.00	F= 8.36 0.00	F= 8.49 0.00

Short-term multipliers					
RER	0.75 [0.59]	0.70 [0.81]	0.66 [0.52]	0.70 [0.54]	0.40 [1.18]
Infrastructure a	1.43*** [0.15]	1.41*** [0.24]	0.84*** [0.14]	0.92*** [0.21]	1.60*** [0.32]
K/L		0.30 [0.53]		-0.24 [0.47]	-0.01 [0.64]
Inflation			-0.04 [0.03]	-0.05 [0.04]	-0.02 [0.05]
TOT					2.75*** [0.91]
Long-term multipliers					
RER	-1.47** [0.59]	-1.71** [0.81]	-1.45*** [0.52]	-1.32** [0.54]	-2.46** [1.18]
Infrastructure a	0.87*** [0.15]	0.76*** [0.24]	0.84*** [0.14]	0.92*** [0.21]	0.99*** [0.32]
K/L		0.30 [0.53]		-0.21 [0.47]	-0.01 [0.64]
Inflation			-0.04 [0.03]	-0.05 [0.04]	-0.02 [0.05]
TOT					0.89 [0.91]
Speed of adjustment towards equilibrium					
Ect. (p-value)	-0.06*** [0.01]	-0.06*** [0.01]	-0.07*** [0.01]	-0.07*** [0.01]	-0.05*** [0.02]

Notes: a) standard errors are in brackets; b) regressions of Table 2 were performed with the introduction of a time trend; c) the intercept and trend parameters are not presented due to limited space, but are available upon request; d) *, ** and *** mean, respectively, statically significant at 10%, 5% and 1%; e) all regressions were performed using the option max lag (3) according to the Akaike information criterion (Aic).

Moreover, the results shown in Table 3 indicate that only infrastructure investments are statistically significant and positively associated with the short-term dynamics of structural change in the Brazilian economy.

5.2 Total factor productivity and labour productivity of manufacturing activities

Table 4 shows the regressions performed to explain the TFP. The results of the long-term multipliers constitute robust evidence that public investment, the ratio capital-labour, and industrialization are positively associated with gains in TFP and vice-versa. The estimated parameters for the Infrastructure b and Infrastructure a[2] variables are statistically significant at 1% of critical values and positive in all regressions. Such empirical evidence suggests that infrastructure and public invest-

[2] Once again it should be stressed that we have performed various estimates with different combinations of the Infrastructure a, Infrastructure b, and Infrastructure c variables. However, not all bound-F-tests have fitted well.

ment expansions may positively influence TFP and vice-versa. At the same time, the estimated parameter for the Industry variable was statistically significant, at 1% of critical values and positive. This suggests that gains in Brazil's TFP are associated with an increase in the country's level of industrialization. Furthermore, our results show that expansions in the capital-labour ratio positively influence TFP. By contrast, our findings have not provided robust evidence that suggests that RER directly influences TFP, as this variable was statistically significant in only one of the regressions in Table 4.

Table 4: Total Factor Productivity

Model	(1)	(2)	(3)	(4)	(5)	(6)
Econometric tests						
Best model (Aic)	(1, 0, 0) -249.1	(1, 0, 0, 1) -261.4	(1, 0, 0) -253.1	(1, 0, 0, 1) -263.9	(1, 0, 0, 0) -239.8	(1, 1, 1, 0) -252.2
BG test (p-value)	0.78	0.76	0.17	0.90	0.66	0.95
Bound F-test (p-value)	F= 5.80 0.01	F= 7.11 0.00	F=7.49 0.00	F= 8.00 0.00	F= 6.61 0.00	F= 4.55 0.03
Short-term multipliers						
RER	-0.17 [0.15]	-0.35*** [0.12]	0.08 [0.15]	-0.13 [0.11]	0.04 [0.09]	0.05 [0.15]
Infrastructure b	0.21*** [0.06]	0.18*** [0.04]				
K/L		0.94*** [0.07]		0.75*** [0.06]		
Industry			0.44*** [0.12]	0.35*** [0.07]	0.36*** [0.07]	1.12*** [0.12]
Infrastructure a					0.10*** [0.03]	
Infrastructure c						0.49** [0.18]
Long-term multipliers						
RER	-0.17 [0.15	-0.35*** [0.12]	0.08 [0.15]	-0.13 [0.11]	0.04 [0.09]	0.05 [0.15]
Infrastructure b	0.21*** [0.06]	0.18*** [0.04]				
K/L		0.18** [0.07]		0.22*** [0.06]		
Industry			0.44*** [0.12]	0.35*** [0.07]	0.36*** [0.07]	0.35*** [0.12]
Infrastructure a					0.10*** [0.03]	
Infrastructure c						0.02 [0.18]

Speed of adjustment towards equilibrium						
Ect. (p-value)	-0.14*** [0.04]	-0.17*** [0.04]	-0.15*** [0.03]	-0.20*** [0.04]	-0.26*** [0.06]	-0.15*** [0.05]

Notes: a) standard errors are in brackets; b) regressions of Table 2 were performed with the introduction of a time trend; c) the intercept and trend parameters are not presented due to limited space, but are available upon request; d) *, ** and *** mean, respectively, statically significant at 10%, 5% and 1%; e) all regressions were performed using the option max lag (3) according to the Akaike information criterion (Aic).

Further, the results shown in Table 4 also indicate that expansions in all independent variables – except for RER – exert a positive influence on the TFP of the Brazilian economy for the short-term dynamic.

Table 5 presents our regressions to explain the labour productivity of manufacturing activities. Regarding the long-term multipliers, our findings suggest that the estimated parameter for the RER variable is statistically significant at 1% of critical values in most regressions, and negative in the sense that a competitive RER is positively associated with manufacturing labour productivity. In turn, the K/L variable has also been shown to ne statistically significant at 1% of critical values, with a positive parameter. This suggests that capital deepening is positively associated with manufacturing labour productivity. Furthermore, we performed various regressions with combinations of our three proxy variables for Infrastructure. However, only the equations using the Infrastructure c variable provided consistent estimations according to the ARDL bounds-testing approach. Thus, we have focused on these estimates. The estimates indicated a positive and statistically significant parameter at 1% of critical values for the Infrastructure c variable in all regressions. This evidence indicates that GFCFs in construction are positively associated with manufacturing labour productivity.

Table 5: Manufacturing labour productivity

Model	(1)	(2)	(3)	(4)
Econometric tests				
Best model (Aic)	(1, 1, 0, 1) -214.7	(1, 1, 0, 0, 1) -214.1	(1, 1, 0, 0, 1) -207.9	(1, 2, 0, 0, 1) -214.3
BG test (p-value)	0.48	0.65	0.68	0.70
Bound F-test (p-value)	F= 4.87 0.02	F= 4.15 0.04	F= 3.67 0.08	F= 4.57
Short-term multipliers				
RER	-0.46*** [0.15]	-0.44*** [0.16]	-0.48*** [0.16]	-0.26 [0.16]
Infrastructure b		0.08 [0.08]		
K/L	1.68*** [6.36]	1.84*** [0.11]	1.76*** [0.18]	1.59*** [0.09]
Industry				0.18 [0.12]

Infrastructure a			-0.02 [0.11]	
Infrastructure c	-0.12 [0.15]	-0.28* [0.16]	-0.11 [0.17]	-0.20 [0.14]
Long-term multipliers				
RER	-0.46*** [0.15]	-0.44*** [0.16]	-0.48*** [0.16]	-0.26 [0.16]
Infrastructure b		0.08 [0.08]		
K/L	0.37*** [0.10]	0.38*** [0.11]	0.41*** [0.18]	0.40*** [0.09]
Industry				0.18 [0.12]
Infrastructure a			-0.02 [0.11]	
Infrastructure c	0.46*** [0.15]	0.46*** [0.16]	0.48*** [0.17]	0.55*** [0.14]
Speed of adjustment towards equilibrium				
Ect. (p-value)	-0.19*** [0.04]	-0.18*** [0.04]	-0.18*** [0.05]	-0.21*** [0.04]

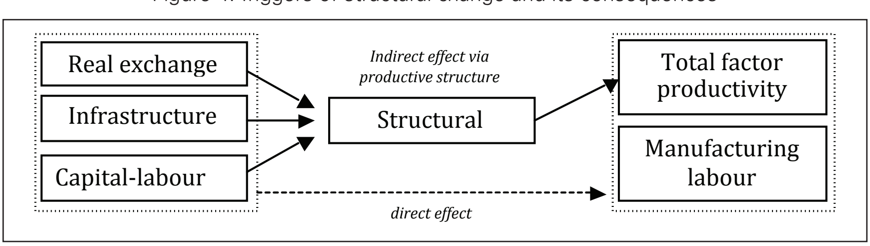
Notes: a) standard errors are in brackets; b) regressions of Table 2 were performed with the introduction of a time trend; c) the intercept and trend parameters are not presented due to limited space, but are available upon request; d) *, ** and *** mean, respectively, statically significant at 10%, 5% and 1%; e) all regressions were performed using the option max lag (3) according to the Akaike information criterion (Aic).

Regarding the short-term multiplier, Table 5 indicates that a competitive RER and greater values of K/L are also positively associated with industrial labour productivity.

5.3 Discussion of the empirical findings

Our main empirical findings show that economic policies associated with RER, public and infrastructure investments, and capital accumulation are intrinsically associated with the structural change of the Brazilian economy. In addition, we identified direct and indirect effects through which policies associated with these three variables may influence Brazil's economic performance, through our two productivity measures, as shown in Figure 4.

Figure 4: Triggers of structural change and its consequences



Source: Authors.

The first channel is the direct effect of the RER, infrastructure investment, and capital-labour ratio in the productive structure of the Brazilian economy. A set of development-oriented economic policies may induce an industrialization process. In this sense, our findings suggest that the RER is part of a consistent explanation for structural change in Brazil. Periods of industrialization were associated with a competitive RER, while a non-competitive RER is part of the explanation for the remarkably swift and substantial deindustrialization. A further possible interpretation derived from our previous results is that public investment and the expansion of physical, social and technological infrastructure comprise an important part of the explanation for the different periods of structural change over the 1950s and 2020s. More specifically, periods of expansion in public and infrastructure investments (developmentalism policies) are connected with manufacturing development, while periods of reductions in these two variables are associated with the intense process of deindustrialization. Moreover, changes in the capital-labour ratio have also been a proven part of the explanation for structural change. Increases in the proportion of capital in relation to labour are linked with periods of industrialization, and vice-versa.

Furthermore, our findings indicate that the effect exerted by the RER, public and infrastructure investment expansions, and the capital-labour ratio is broader. In line with our empirical findings, there is evidence that the three variables mentioned are also directly associated with manufacturing labour productivity and indirectly associated with the TFP through the process of structural change. Therefore, a competitive RER, expansions in public and infrastructure investment, and an augmented machinery stock relative to employed workers boost our two productivity measures – in line with what happened in Brazil's industrialization period from 1950 to the mid-1980s, as shown in section 3.

In the last decades of intense premature deindustrialization, the RER was non--competitive for most of the period. The effect was to discourage domestic industrial production in favour of imported inputs and final goods that encouraged labour-intensive assembly processes rather than industrial transformation through the introduction of modern machinery – thus reducing the capital-labour ratio (Morceiro, 2018; Morceiro and Guilhoto, 2020). Privatizations, the new social pact, and fiscal responsibility measures also acted to reduce public and infrastructure investments as a proportion of GDP. The removal of development-oriented policies led to lower growth as new capital additions per worker were discouraged – and negatively impacting productivity, as shown in section 3.

Therefore, the dynamics of the three variables of interest in this article with Brazil's structural change process and productivity (manufacturing and TFP) are consistent with our econometric findings. Further, structural change is a complex process, in which several variables may act alone or interact with other variables. In this article, we use the main variables thought to explain the structural change in Brazil that are available for periods longer than six decades. While variables such as industrial policy certainly contribute to explaining structural change in the country, it is not easy to model it econometrically.

6. CONCLUDING REMARKS

Through our new and robust empirical findings, this study broadens the understanding of the long-term drivers of structural change during the peak period of economic growth in Brazil, characterized by industrialization, and the decline in Brazil's economic growth, characterized by premature deindustrialization, over the past seven decades. Following the arguments of Palma (2005) and Tregenna (2016), we argue that part of premature Brazilian industrialization is due to a change from policies oriented to economic development (as those implemented between the 1950s and 1980s) towards neoliberal policies associated with fiscal consolidation – which has reduced infrastructure investments and public investment, and inflationary control via the pursuit of an overvalued RER. To put it in another way, our argument is that the premature deindustrialization experienced by the Brazilian economy is linked to changes in economic policies from an institutional regime based on the state-led industrialization towards neoliberal economic and political reforms.

Our results indicated that expansions in investments in infrastructure, a competitive RER, and a greater capital-labour ratio are the three variables positively associated with periods of industrialization, in terms of GDP share and manufacturing employment. This roughly corresponds to the period between 1947 and 1980, when the central government adopted development-oriented policies that promoted industrialization. These policies were instrumental in driving the industrial development of the Brazilian economy until the mid-1980s. In contrast, changes in the conduct of macroeconomic policies from the mid-1980s sparked the intense process of premature deindustrialization in the Brazilian economy. These included the use of the RER as a nominal anchor to control the inflation rate and the fiscal crisis of the Brazilian State, which, when considered in light of the external crisis, led to the reduction of public investment and the move away from development-oriented policies and institutions in the 1990s to pursue fiscal consolidation.

Our empirical findings show that investments in infrastructure, a competitive RER, and an enhanced capital-labour ratio, also exert a direct and positive influence on total factor productivity and manufacturing labour productivity. This means that the change in macroeconomic policies discussed above – from a development approach to more fiscal and inflationary control – partially explains the decline in total factor productivity and manufacturing labour productivity. This is apart from the indirect effect via the structural change brought about by the premature deindustrialization process. In this sense, the deindustrialization process largely explains Brazil's decline in total factor productivity over the last decades.

Based on our long-term empirical findings, we believe that this study may be useful in informing future economic policy to reindustrialize the Brazilian economy and boost economic growth. A strategy to promote consistent growth requires an institutional amendment which facilitates the expansion of infrastructure through public investment. This is not allowed under the current fiscal rules as there is a legal limit to the level of adjustments that can be made in the government budget, which is actually leading to a drop in public investments. We believe therefore that the parameters of fiscal policy in Brazil should be revised. Similarly, an appropriate configuration of macroeconomic conditions in terms of monetary and fiscal policies and income redistribution (conflict distributive) is necessary to pursue a competitive RER without a sharp increase in inflation. The recovery of infrastructure investment and competitive RER drivers can provide the kickstart to a virtuous path of catching-up based on reindustrialization. This can then unlock the third drive (deepening of capital stock per worker) that is vital for industrial modernization in the context of digitalization and the fourth industrial revolution.

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