Mudança Estrutural, Infraestrutura e Taxa de Câmbio Real no Brasil: desenvolvimento e declínio da indústria

Structural Change, Infrastructure and Real Exchange Rate in Brazil: development and decline of the manufacturing industry

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Abstract: This article investigates the macroeconomic causes of structural change – the development and the decline of the manufacturing industry - of the Brazilian productive structure and its consequences in terms of total factor productivity and manufacturing labor productivity over the period from 1947 to 2021. Our results suggest that changes in Brazilian productive structure – industrialization and deindustrialization – are associated with the conduct of policies of investment in infrastructure and the real exchange rate. Further, the article also provides evidence that these variables exert a direct influence on the total factor productivity and the manufacturing labor productivity and an indirect influence through their impacts on the Brazilian productive structure.

Keywords: Structural Change; Infrastructure, Public Investment; Real exchange rate; Brazil.

Resumo: Este artigo investiga as causas da mudança estrutural – o desenvolvimento industrial e a desindustrialização – da estrutura produtiva brasileira e as suas consequências em termos da produtividade total dos fatores e da produtividade da mão de obra industrial entre 1947 e 2021. Os resultados do estudo indicam que alterações na composição da estrutura produtiva brasileira – industrialização e desindustrialização – estão associadas à condução dos investimentos públicos e em infraestrutura, bem como da taxa de câmbio real. O artigo sugere ainda que essas variáveis exercem uma influência direta positiva sobre a produtividade total dos fatores e sobre a produtividade da mão de obra industrial e uma influência indireta através de seus impactos na estrutura produtiva brasileira.

Palavras-chave: Mudança estrutural, Infraestrutura, Investimento Público, Taxa de Câmbio Real, Brasil.

JEL Code: O1, O11, O14

Área 6 - Crescimento, Desenvolvimento Econômico e Instituições

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1- Introduction

Economic growth is a process of a structural change in the sectoral composition of gross domestic product (Ocampo et al., 2009), which is interrelated with changes in population, technological progress, and consumption patterns, with consequences in terms of production, employment, and prices (Pasinetti, 1981). The richer countries of the world are those with most of the population employed in high-productivity and modern sectors, like the manufacturing industry. The long-run growth is positively associated with the composition of productive structure, so that the industrialized economies are those more prosperous (Kaldor, 1966). The promotion of structural change (i.e., the transfer of resources from agriculture and services toward manufacturing sectors a la Lewis (1954)) and policies associated with this purpose are the fundamental driver of economic growth (Rodrik, 2013).

In this sense, literature – both empirical and theoretical – indicates the importance of an active policy regarding investments in infrastructure and the conduct of real exchange rate to boost long-run performance. There are many transmission channels through which both variables influence economic growth. Public investment has a direct effect on short-run output as many growth models consider it as an additional variable in the production function (Barro, 1990, Valila, 2020). Infrastructure has an indirect effect on long-term growth by influencing the marginal productivity of capital, the total factor productivity, by inducing efficiency gains via the international market insofar as a better infrastructure reduces unitary costs (Barro, 1990, Bogetic and Fedderke, 2005, Agénor and Moreno-Dodson, 2006, Valila, 2020). In its turn, a competitive real exchange rate is associated with the composition of productive structure and then with long-run growth as it influences the profitability of tradable sectors, which encompass the manufacturing activities (Rodrik, 2008, Bahlla, 2012, Oreiro et al. 2020, Marconi et al., 2021). A competitive real exchange rate is associated with capital accumulation and technological progress of manufacturing sectors, with reverberant effects on labor productivity, total factor productivity and then economic growth (Bahmani-Oskooe and Hajilee, 2010, Mbaye, 2013, Rapetti, 2020, Demir and Ramzi, 2021).

In light of these arguments, the Brazilian economy is in the opposite direction of a solid long-run path of growth as its productive structure has been suffering a deindustrialization process and regressive specialization since the 1980s, after a long period of development-oriented policies associated with the promotion of industrialization since the 1940s (Coutinho, 1997, Nassif et al. 2015, Nassif, et al. 2016; Oreiro, et al. 2018, Morceiro and Guilhoto, 2020, among others), with negative effects over labor productivity and total factor productivity. Our argument is that this is due to the conduct of economic policies regarding the public investment in infrastructure and the real exchange rate. Put differently, the structural change – industrialization and deindustrialization – within the productive structure of the Brazilian economy over the period from 1947 to 2021 is associated with changes in the above-mentioned economic policies.

In this article, we intend to investigate the macroeconomic causes of structural change – the development and the decline of the manufacturing industry - of the Brazilian productive structure and its consequences in terms of total factor productivity (TFP) and manufacturing labor productivity over the period 1947-2021. For that, time series 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). Our findings indicate that infrastructure, expansions in public investment, and a competitive real exchange rate, are positively associated with periods of industrialization of

Brazilian productive structure and gains in TFP and manufacturing labor productivity. Complementarily, our estimates indicate a positive and indirect effect of these variables on TFP via its industrializing effects on the Brazilian productive structure.

The contribution to the existing literature on the causes of structural change in Brazil is various. First, we combine various sources of data for Brazil from 1947 to 2021, covering different periods of structural change, specifically the industrialization and the deindustrialization periods. To the best of our knowledge, this study is pioneering in providing 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 literature like real exchange rate. Further, our study is also pioneering in demonstrating the direct effects of these variables on TFP and manufacturing labor productivity, as well as its indirect effect via its influence on changes in the productive structure. Our study may be helpful to design a suitable policy for the reindustrialization of the Brazilian productive structure.

The rest of the paper is structured as follows. The second section discusses the literature on the importance of structural change for economic growth, and the role played by investment in infrastructure, and real exchange rate in promoting economic growth. The third section discusses the empirical strategy adopted in our econometric regressions. Fourth section presents and discusses our empirical findings. At last, conclusions close the study.

2- Conceptual framework

In this section, we briefly discuss why the structural change in the direction of the manufacturing industry plays a critical role in economic growth and the channels through which investments in infrastructure and the real exchange rate influence economic growth.

2.1- Structural Change and Economic Growth

Structural change towards the manufacturing industries and modern sectors – understood as a process of creative destruction in the Schumpeterian sense and as diversification of productive structure - is one of the elements that explain why some economies exhibit greater long-run growth (Ocampo, 2005). A structural change within the productive structure toward non-traditional activities (such as manufacturing sectors), or diversification of the productive structure beyond services and primary sectors, is the engine of long-run path growth (Kaldor, 1966). This is widely known as the first Kaldor's law, and there is robust literature that supports its statement (e.g., Szirmai, 2012, Ros, 2015, Marconi et al., 2016, Weiss and Jalilian, 2016, Cantore et al. 2017, Haraguchi et al., 2017, Gabriel and Ribeiro, 2019). There are many arguments in the literature according to which the development of manufacturing sectors is positively associated with long-run growth. Industrialization induces sectoral integration within the productive structure through backward and forward links with other sectors (Hirschman, 1958, Tregenna, 2008), which increases its scope for externalities over the whole economy (Weiss and Jalilian, 2016). The manufacturing industry has the more prominent ability to generate technological progress, a faster pace of capital accumulation, and of labor productivity growth (Tregenna, 2008, Szirmai, 2012). Manufacturing activities exhibit dynamic increasing returns of scale in the sense that higher demand growth is positively associated with labor productivity growth (Verdoorn, 1949, Kaldor, 1966). As the resources employed (mainly the labor) in traditional sectors are absorbed by the manufacturing activities, the labor productivity and real wages of the whole economy increase (Lewis, 1954, Kaldor, 1966, Ros, 2015). As a tradable activity, there is a large potential for gains via international trade (Weiss and Jalilian, 2016). Further, manufacturing development is associated with the creation of better jobs (formal and with greater real wages) and with a more significant contribution of human capital and institutions to economic growth (Su and Yao, 2016).

2.2- The Role of Infrastructure and Real Exchange Rate in Economic Growth

There is consensus that investment in infrastructure and the real exchange rate exert an influence on the process of economic development, or on the long-run growth. There are many reasons why augmented infrastructure investments and/or a competitive real exchange rate have benefits on economic development.

Many growth models have been incorporating public investment in infrastructure within their framework in order to study the determinants of economic growth. In the empirical literature, although with considerable analytical heterogeneity, the pioneering studies of Mera (1973), Ratner (1983), and Costa et al. (1987) indicated a positive influence of public investment on output. However, only after the breakthrough contribution of Aschauer (1989) – who empirically demonstrated the strategic role played by the public investment in determining the total factor productivity United States of America economy, or specifically the positive association between public capital (stock and flow) and productivity, such an association became a frequent issue in growth studies. Aschauer (1998) provided evidence that public investment is positively associated with the long-term growth of 46 developing countries over the period from 1970 to 1990, stressing the importance of the reallocation of government consumption to public investment as a sound source of financing for the expansion of public investment. Various studies confirmed the importance of investment in infrastructure to expand output (e.g., Easterly and Rebelo, 1994, Barro and Sala-i-Martin, 1995, Sanchez-Roblez, 1998, Esfahani and Ramirez, 2002, Straub, 2008, Égert, et al., 2009, Warner, 2014, ADB et al., 2016, among others).

There is extensive and very heterogenous cross-country literature on the influence of public capital on output. Bom and Ligthart (2014) analyzed 578 estimates of the output elasticity of public capital from literature to synthesize their results, focusing on studies that employed the production function Cobb Douglas approach. The survey provided by the authors indicated an average output elasticity in relation to public capital of around 0.10. Though the literature's output is very diverse due to the use of different data, methods, and samples (Straub, 2008, Bom and Ligthart, 2014, Valila, 2020).

In turn, in the theoretical literature, investment in infrastructure has been increasingly considered an important driver of long-term growth. Literature indicates various transmission channels, with the existence of direct and indirect effects, from changes in infrastructure capital to economic growth. Expansions in infrastructure – or public capital – increase the productivity of labor and stock of private capital used in a typical Cobb Douglas function of neoclassical growth models (Barro, 1990, Agénor and Moreno-Dodson, 2006, Valila, 2020). As a result of such an endogenous growth-approach, policies of instigating the infrastructure investment are associated with a greater total factor productivity (Barro, 1990, Valila, 2020). Moreover, public capital favors the private decisions of making new investments insofar as improvements in infrastructure reduce unit production costs and expand the marginal productivity of private capital (Agénor and Moreno-Dodson, 2006, Valila, 2020). Further, there exists 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, inducing production and investments (Bogetic and Fedderke, 2005, Agénor and Moreno-Dodson, 2006, Sahoo and Dash, 2009), besides an additional positive effect on innovative pressures stemmed from the entering of national production in international markets (Bogetic and Fedderke, 2005, Valila, 2020). In addition, investments in infrastructure may induce expansions in labor productivity because it improves the workers' access to roads, public transportation, electricity, and telecommunications, which leads to enhanced economic growth and alleviated poverty (Agénor and Moreno-Dodson, 2006, Straub, 2008, Sahoo and Dash, 2009). Complementarily, as better public capital as increased the durability of private capital (Agénor and Moreno-Dodson, 2006, Straub, 2008).[3]

On the other hand, there is well-established empirical literature on the positive effects of a competitive real exchange rate on economic growth (e.g., Cottani et al., 1990; Dollar, 1992; Razin and Collins, 1997; Aguirre and Calderón, 2005; Rodrik, 2008; Bahlla, 2012; Gabriel et al., 2020; Rapetti, 2020; Ramzi, 2021). In theoretical literature, there are many transmission channels through which the real exchange rate affects economic growth. The "profitability channel" indicates that a competitive real exchange rate expands the profitability of tradable sectors as it lowers labor costs and enlarges export revenues (Bahlla, 2012). Further, there is the "distributive effect" as a competitive real exchange rate 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 real exchange rate leads to an "investment effect" as firms tend to increase their investment (as a result of the accumulated/augmented profits). In other words, it instigates the capital accumulation of tradable activities to detriment of consumption, which leads to the "structural change effect" insofar as it induces a transformation in productive structure by benefiting manufacturing sectors and diversifying the productive structure (Rodrik, 2008, Missio et al., 2015; Oreiro et al. 2020, Marconi et al., 2021), with reverberant effects over technological progress (Rodrik, 2008; Bahmani-Oskooe and Hajilee, 2010) and over the total factor productivity (Mbaye, 2013). The "development channel" summarizes these effects: a competitive real exchange rate induces capital accumulation, productivity factors, the allocation of resources, the productive structure, favoring economic growth (Rapetti, 2020, Demir and Ramzi, 2021).

In sum up, as the conduct of government policy regarding the investment in infrastructure – or public capital - as the maintenance of a competitive real exchange rate are important part of a consistent growth-enhancing strategy.

3. Empirical procedures

This section discusses the database and the empirical strategy used in our regressions.

3.1- Database

The empirical strategy consists of estimating a set of time-series regressions to understand the influence of development policies over the Brazilian productive structure. The

[3] We concentrated our analysis on the macro-aspects of the association between infrastructure. There is a vast literature on the micro-aspects of such an association. See Dissou and Didic (2013) for an ample survey.

dependent variables used in our regressions are i- the manufacturing GDP as a share of total GDP (Industry), ii- the employment in manufacturing activities (Employment), iii- Total Factor Productivity (TFP), and iv- labor productivity of manufacturing activities (Productivity). Table 1 provides more details about these variables.

Table 1- Variables

Variable	Definition and sample	Source
Industry	Manufacturing GDP as a share of total GDP (1947-2021)	Calculated by Morceiro (2021) using data from Brazilian Institute of Geography and Statistics (IBGE)
Employment	Employment in manufacturing activities (1950-2019)	Calculated by the authors by applying the manufacturing employment's annual rate of change from various sources to the 2019 manufacturing employment. Sources of annual variation for each period are: 1950-1976 (Timmer, De Vries, & De Vries, 2016), 1977-1990 (IBGE, 2006), 1991-2000 (IBGE, 2004) e 2001-2019 (IBGE, 2021)
TFP	Total Factor Productivity (1954-2019)	Penn World Table 10.0
Productivity	Manufacturing labor productivity (1950-2019)	Authors' calculations using IBGE National Accounts data for the value-added variable. See the previous for the employment variable
RER	Real Exchange Rate (1960-2020)	Darvas (2021)
Infrastructure a	Gross fixed capital formation 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 industrial employment (1950-2017)	Júnior and Cornelio (2020) for the value-added variable. See the previous for the employment variable
Infl	Inflation rate (1947-2021)	Institute of Applied Economic Research (IPEA)
TOT	Terms of trade: the ratio of prices of exports and of imports (1947-2021)	Institute of Applied Economic Research (IPEA)

Source: authors

The variable Industry was provided by Morceiro (2021). The variable Employment was calculated by the authors using information from different sources, described in Table 1. In turn, the variable TFP comes from the Penn World Table 10.0, while Productivity was calculated by the authors using different databases. It is important to notice that our variables have different time spans. We strived to maximize the years contained in our sample.

We estimated a log-linear functional specification to explain our dependent variables. The equations performed to explain the structural composition of Brazilian economy – represented by the variables Industry and Employment - are presented below.

$$Industry_t = c + b_1RER + b_2Infra + b_3K/L + b_4Infl + b_5Productivity + b_6TOT + \varepsilon_t \quad (1)$$
$$Employment_t = c + b_1RER + b_2Infrastructure + b_3K/L + b_4Infl + b_5TOT + \varepsilon_t \quad (2)$$

In its turn, the log-linear functional specification used in our empirical estimates to explain TFP and Productivity are presented below.

$$TFP_t = c + b_1RER + b_2Infrastructure + b_3K/L + b_4Industry + \varepsilon_t \quad (3)$$
$$Productivity_t = c + b_1RER + b_2Infrastructure + b_3K/L + b_4Industry + \varepsilon_t \quad (4)$$

The parameter *c* is a constant term. The variable real exchange rate is our measure of the real exchange rate provided by Darvas (2021). This variable was introduced in our estimates to capture the notion above-discussed according to which a competitive real exchange rate induces the industrialization of productive structure (Rodrik, 2008, Ros, 2015, Gabriel and Missio, 2018, Oreiro et al, 2020, Iasco-Pereira and Missio, 2022), with possible reverberant effects over total factor productivity and manufacturing labor productivity (Mbaye, 2012). We take the logarithm of its original values (divided by 100). Negative (positive) values represent a devalued (overvalued) real exchange rate in relation to the year-base. A negative parameter in estimates means that a competitive real exchange rate is positively associated with our dependent variable, vice-versa.

Further, we employed three different variables to capture the investment in infrastructure. The first one is Infrastructure a, which stands for the gross fixed capital formation in infrastructure over the period from 1947 to 2017 and comes from Júnior and Cornelio (2020). The second variable, represented by Infrastructure b, is the public investment as a share of GDP for the period 1947-2020, and comes from Pires (2022). It is usual in literature the use public investment as a proxy for infrastructure investment, though it should be aware that it excludes the non-public investment in infrastructure which limits the analysis (Välilä, 2020). The third variable, represented by Infrastructure c, is the investment in construction as a share of GDP over the period from 1947 to 2020, and comes from Júnior and Cornelio (2020). These variables depict the flow of public investment in infrastructure within a macroeconomic perspective, as it is usually employed in literature (e.g., Aschauer, 1989, 1998, Straub, 2008, Välilä, 2020).

An argument developed by Haraguchi (2015) is that the dynamic of industrialization is associated with different capital and technology intensities over time. As industrialization takes place over the different manufacturing sectors from early and middle industries labor-intensive (like basic metals) to late industries less labor-intensive (like electrical machinery), there is an increasing capital and technology intensity in the production process (Haraguchi, 2015). We introduce the variable K/L in our regressions - the ratio of investment in machinery and industrial employment – in order to capture this argument.

The variable Inflation was introduced in our regressions to capture the notion according to which the macroeconomic stability may influence our dependent variables. We argue that macroeconomic instability, which is represented by a high inflation rate, hinders the industrialization process, as well as gains in total factor productivity and manufacturing labor productivity. The variable TOT represents the evolution of the terms of trade, calculated as the ratio of exports and imports price. Such a variable captures the argument of Bresser-Pereira (2016) according to o which greater terms of trade generated the Dutch Disease, contributing to the deindustrialization of the Brazilian economy. All dependent variables used in our regressions are described in Table 1, above.

3.2- 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 at al. (2001). Such a methodology has several advantages in relation to cointegration methods of Engle and Granger (1987), and Johansen (1988): i- the ARDL approach is an appropriated method when variables are I(0), I(1), or a combination of I(0) and I(1) variables[4]; ii- the ARDL estimates are appropriated to investigate the long-run relationship for a small sample; iii- variables are used in different lags, which improves the efficiency of estimates; iv- the short- and long-run relationships are estimated within a single equation, instead of a system of equations.

The appropriated number of lags was chosen according to the Akaike Information Criterion (AIC). We tested the existence of a long-run 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: $\delta\neq0$). In the case of not accept the null hypothesis (that is, there is a long-run relationship between our variables), the long-run multipliers are represented by estimated coefficients for the dependent variables in level, while the short-run multipliers are the estimated coefficients for the dependent variables in 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 been shown important to check the results' robustness, and to avoid a possible collinearity. Moreover, not all combinations are associated with a cointegration relationship between our variables, which is required to obtain meaningful estimates. Thus, we presented only regressions that rejected the bounds testing procedures' null hypothesis. The next section presents our empirical findings.

4. Empirical findings

Our estimates are discussed in what follows. All regressions have fitted well. The Breusch Pagan test has indicated a non-correlated error term. The bounds testing procedure pointed out the existence of a long-run relationship between our variables at least at 5% of critical values (at 1% for most of regressions). The estimated parameter for the speed of adjustment towards equilibrium was negative and statistically significant in all regressions.

4.1- Structural change

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[4] Although literature suggests no need for unit root tests, we provide a Table with the usual tests in appendix. No variable has shown I(2).

Table 2 presents the regressions performed to explain the industrial share of GDP (industry). Regarding the long-run multipliers, our findings indicated the importance of real exchange rate, social infrastructure, and capital accumulation in relation to employed workers to explain why the Brazilian economy has been experiencing a deindustrialization/industrialization process within its productive structure since only these variables were statistically significant. The estimated parameter for the variable real exchange rate 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 real exchange rate is associated with a structural change in direction of manufacturing activities. On the other hand, a non-competitive real exchange rate is part of the explanation for the deindustrialization of the Brazilian economy. Further, the estimates suggest a positive parameter for the variables Infrastructure a[5] and K/L. This piece of evidence indicates that social infrastructure and capital accumulation are positively associated with the development of manufacturing sectors within Brazilian economy.

In relation to the short-run multipliers, our findings confirmed the positive association between a competitive real exchange rate, social infrastructure, and capital-labor ratio with industrial development of Brazilian economy. Table 2 is presented below.

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-run 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]

[5] 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.

Long-run 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]
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 between brackets; b- regressions of Table 2 were performed with the introduction of a time trend; c- intercept and trend parameter are not presented due the limited space, which is available upon request; d- *, ** and *** mean, respectively, statically significant at 10%, 5% and 1% respectively; e- all regressions were performed using the option max lag(3) according to the Akaike information criterion (Aic).

Table 3 reports the regressions performed to explain our other measure of changes in productive structure, employment in manufacturing activities (Employment). Its findings are in line with Table 2's results. The estimated long-run multipliers indicated the importance of real exchange rate, and social infrastructure to explain changes in employment in manufacturing activities. The estimated parameter for real exchange rate was statistically significant (at least at 5% of critical values) and negative in all regressions. Thus, a competitive real exchange rate is positively associated with manufacturing employment. In its turn, the estimated parameter for the variable Infrastructure a is also positive and statistically significant at 1% of critical values in all equations of Table 3. This indicates that expansions in social infrastructure may spark the creation of jobs in manufacturing activities, and vice-versa. Put differently, economic policies associated with pursuing a competitive real exchange rate and greater values of investments in infrastructure unleash a structural change in the Brazilian economy by transferring workers from non-industrial activities to manufacturing a la 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-run 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-run 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 between brackets; b- intercept is not presented due the limited space, which is available upon request; c- *, ** and *** mean, respectively, statically significant at 10%, 5% and 1% respectively; d- all regressions were performed using the option max lag(3) according to the Akaike information criterion (Aic).

Table 3's results indicate that only the positive influence of social infrastructure is statistically significant for the short-run dynamic of the Brazilian productive.

4.2- Total factor productivity and labor productivity of manufacturing activities

Table 4 displays the regressions performed to explain the TFP. The results of the long-run multipliers delivery robust evidence that public investment, the ratio capital-labor, and industrialization of the productive structure are positively associated with gains in TFP, and vice-versa. The estimated parameters for the variables Infrastructure b and Infrastructure a[6] are statistically significant at 1% of critical values and positive in all regressions. This shred of evidence is suggestive that expansions of infrastructure and public investment may exert a positive influence on TFP, and vice-versa. Complementarily, the estimated parameter for the variable Industry was statistically significant at 1% of critical values and positive. This is an indicative that gains of Brazil's TFP are associated with the industrialization of Brazilian productive structure. Further, our results also indicate that expansions in capital-labor ratio also exert a positive influence on TFP. In contrast, our findings have not provided robust evidence that real exchange rate directly exerts a direct influence on TFP, since this variable was statistically significant in only one of Table 4's regressions. Table 4 is presented below.

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-run 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-run 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***	0.35***	0.36***	0.35***

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

			[0.12]	[0.07]	[0.07]	[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 between brackets; b- intercept and trend parameter are not presented due the limited space, which is available upon request; c- *, ** and *** mean, respectively, statically significant at 10%, 5% and 1% respectively; d- all regressions were performed using the option max lag(3) according to the Akaike information criterion (Aic).

Table 4's results also indicate that expansions in all dependent variables – except for real exchange rate, exert a positive influence on TFP of Brazilian economy for its short-run dynamic.

Table 5 presents our regressions performed to explain the labor productivity of manufacturing activities within Brazilian economy. Regarding the long-run multipliers, our findings suggest that the estimated parameter for the variable real exchange rate is statistically significant at 1% of critical values in most regressions and negative in a manner that a competitive real exchange rate is positively associated with manufacturing labor productivity. In its turn, the variable K/L has also been shown statistically significant at 1% of critical values, with a positive parameter. This is an indication that the capital-labor ratio is positively associated with manufacturing labor productivity. Further, we performed various regressions with several combinations of our three variables proxy for social infrastructure. Yet, only the equations employing the variable Infrastructure c provided consistent estimations according to the ARDL bounds testing approach. Thus, we have focused on these estimates. The estimates indicated a positive parameter for the variable Infrastructure c (statistically significant at 1% of critical values and positive in all regressions). This piece of evidence is suggestive that social infrastructure is positively associated with manufacturing labor productivity. Table 5 is presented below.

Table 5- Manufacturing labor 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-run 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-run 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]

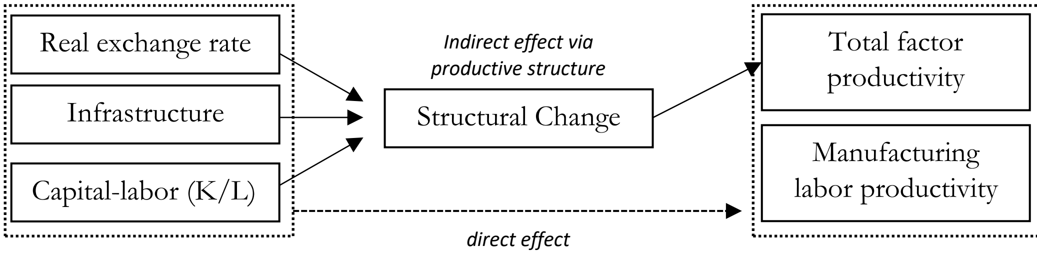
Notes: a- standard errors between brackets; b- intercept and trend parameter are not presented due the limited space, which is available upon request; c- *, ** and *** mean, respectively, statically significant at 10%, 5% and 1% respectively; d- all regressions were performed using the option max lag(3) according to the Akaike information criterion (Aic).

Regarding the short-run multiplier, Table 5 indicates that a competitive real exchange rate and greater values of K/L are also positively associated with industrial labor-productivity.

4.3- A discussion on our empirical findings

Our empirical results reveal that economic policies associated with real exchange rate, investments in infrastructure, and capital accumulation are intrinsically associated with the structural change of Brazilian economy. We identified two channels (a direct and an indirect) through which policies associated with these variables may influence Brazilian economic performance, as it is described in Figure 1.

Figure 1- Triggers of structural change and its consequences



Source: authors

The first channel is the direct effect exerted by real exchange rate, investment in infrastructure, and capital-labor ratio on the Brazilian productive structure. A development-oriented set of economic policies may induce an industrialization process. In this sense, our findings suggest that the real exchange rate is part of a consistent explanation for structural change within Brazilian economy. Periods of industrialization are associated with a competitive real exchange rate, while a non-competitive real exchange rate is part of the explanation for its remarkable deindustrialization.

A further possible interpretation derived from our previous results is that public investment and social infrastructure compound an important part of the explanation for the different periods of structural change that occurred within the Brazilian economy over the 1950s and 2020s. More specifically, periods of expansions of public investment and improvements in social infrastructure (developmentalism policies) are connected with periods of manufacturing development, while periods of reductions in these variables (after the 1980s, for example) are combined with the deindustrialization of productive structure.

Moreover, changes in the ratio of capital-labor have also been proved part of the explanation for structural change within Brazilian economy. Increases in the proportion of capital in relation to labor are linked with periods of industrialization, and vice-versa.

However, our results indicate that the direct effect exerted by real exchange rate, public investment, social infrastructure, and the capital-labor ratio is broader. In line with our previous findings, there is evidence that the mentioned variables are also associated with TFP and manufacturing labor productivity. A competitive real exchange rate, expansions in public investment and in social infrastructure, as well as an augmented machinery in relation to employed workers, push up both variables.

The second channel is the indirect effect exerted by real exchange rate, public investment, social infrastructure, and capital-labor ratio on TFP. As these variables are associated with the development of productive structure, they expand the Brazilian economy's TFP by promoting its industrialization in terms of manufacturing share of GDP.

5- Concluding remarks

Our study is an effort to comprehend the drivers behind the structural change within the Brazilian productive structure over the period from 1947 to 2021. Our results revealed important aspects in relation to the structural composition of the Brazilian economy. First, expansions of investments in infrastructure, a competitive real exchange rate and a greater capital-labor ratio are positively associated with periods of industrialization, which roughly corresponds to the period between 1947 and 1980 when the development-oriented policies, associated with the promotion of industrialization, were adopted by the central government. Such policies induced the industrial development of the Brazilian economy until the 1980s. In contrast, changes in the conduct of macroeconomic policies after the 1980s - like the use of the real exchange rate as a nominal anchor to control the inflation rate, the fiscal crisis of the Brazilian state that, when considered in association with the external crisis, had led to the reduction of public investment and the deconstruction of development-oriented policies and institutions over the 1990s in order to pursue the fiscal consolidation – have sparked the process of deindustrialization and regressive specialization of the Brazilian economy. In this sense, our results also revealed that such deindustrialization productive structure is part of the explanation for the decline of total factor productivity of Brazil.

On the other hand, our findings point out that the investments in infrastructure, a competitive real exchange rate, as well as capital-labor ratio, also exert a direct and positive influence on the total factor productivity and the manufacturing labor productivity. Ergo, the above-mentioned change in macroeconomic policies (i.e., from a development orientation to fiscal and inflationary control orientation) is part of the explanation for the decline in total factor productivity and manufacturing labor productivity, besides the indirect effect via the structural composition of the productive structure.

This study has some implications in terms of economic policy in order to reindustrialize the Brazilian economy. A consistent strategy for that requires an institutional amendment to enable expansions in infrastructure via public investment. Currently, the existing fiscal rules do not allow it, since there is a legal limit to readjusting the government budget that imposes a deterioration in public investments. Thus, the parameters of fiscal policy in Brazil should be revised. In turn, it is necessary a suitable configuration of macroeconomic conditions in terms of monetary, fiscal policies and income redistribution (conflict distributive) to pursue a competitive real exchange rate without a sharp inflation acceleration.

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