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Revisiting the growth of the Brazilian economy (1980-2012)

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Abstract:

The objective of this article is to analyze the causes of growth deceleration in the Brazilian economy initiated in the mid-1980s from a Keynesian-Structuralist perspective, according to which long-term growth is associated with structural change and capital accumulation. The article will analyze the period from 1980 to 2012 and will test the hypothesis that growth slowdown was caused by a large reduction in the rate of capital accumulation, due to a substantial reduction of the investment share in real output that begun in the 1980s and increased in the 1990s. The reduction of the investment share was the result of the existing imbalances of macroeconomic prices (mainly overvalued real exchange rate and exchange rate/wage ratio) which caused a premature deindustrialization of the Brazilian economy, with negative effects on investment opportunities. The obtained econometric results demonstrate the theoretical hypothesis regarding growth deceleration of the Brazilian economy.

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Between the 1930s and the 1980s, the Brazilian economy underwent a profound process of structural change, shifting from a primary export based economy to an urban and industrialized economy. During these fifty years, real GDP grew at an average rate of 7% per year, while GDP per capita increased at an average rate of 4% per year, causing GDP and GDP per capita to double in size every 10 and 17.5 years, respectively. The 1980s marked the end of the accelerated growth phase of the Brazilian economy, after which began a long period where the growth rate ranged from moderate (2003-2012) to low (1990-2002). The new

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phase of economic development in Brazil was termed "semi-stagnation" by Bresser-Pereira (2007). In this context, the article aims to analyze the causes of the economic growth deceleration in Brazil, based on a Keynesian-Structuralist theoretical framework, according to which economic development consists of the increase in the population's standard of life, enabled by the growth of labor productivity. The latter depends on structural change or productive sophistication (transfer of labor and other resources from activities with lower added-value per capita to activities with higher added-value) and capital accumulation.

This article demonstrates that the pace of capital accumulation has declined significantly since the late 1980s, and that this reduction was primarily caused by the decrease in the investment rate at current prices. In addition, the share of the manufacturing industry in GDP also presented a clear reduction trend from the beginning of the 1980s. This is associated to the macroeconomic instability in the second half of that decade, to the overvaluation of the real exchange rate observed from the beginning of the 1990s, and to the adoption of the liberal-dependent model of external savings from 1994 onwards.

The estimates carried out in this article show that the rate of growth of labor productivity depends on the dynamics of the manufacturing share in GDP and the growth rate of the capital stock per worker. In turn, the evolution of the manufacturing share in GDP depends on the rate of exchange rate undervaluation, and negatively depends on the technological gap. The estimation of the investment function shows that the investment share is a quadratic function of the exchange rate/wage ratio, a positive function of the level of capacity utilization and a negative function of the country risk premium.

It is possible to conclude, based on the empirical results, that the deceleration of economic growth since 1980 was due to the combined effects of the reduction of investment rate at current prices and the decrease in the manufacturing share in GDP. The reduction in the investment rate is mainly due to the macroeconomic regime that prevailed since 1994, which restricted the expansion of aggregate demand, maintaining the capacity utilization at a low level. Another important factor in explaining this phenomenon was the external fragility of the Brazilian economy, which was expressed in a currency crisis that was responsible for maintaining a high country risk premium, causing a negative impact on investment. However, the exchange rate overvaluation observed from the beginning of the 1990s and beyond seems to have had a positive impact on the investment rate. The negative effect of the real exchange rate appreciation on growth was due to the dynamics of the manufacturing share in GDP. It will be demonstrated that: (i) the reduction of the manufacturing share in the GDP has a strong negative impact on the rate of growth of output per worker, and (ii) the appreciation of the real exchange rate negatively affects the share of manufacturing industry, with a one-year lag. Thus, the trend of exchange overvaluation after 1994 had a negative net impact on growth.

1. Economic development and the technical progress function

Economic development is a process whereby capital accumulation and the systematic incorporation of technical progress permit the persistent increase in labor productivity and population standard of living (Bresser-Pereira et al., 2014). The increase in labor productivity enables the persistent raise in real wages once the so-called "Lewis point" has been overcome; that is, once the labor force employed in the subsistence sector has been fully transferred to the modern sectors (Lewis, 1954). At that point, the unlimited supply of labor, characteristic of

Capitalism Phase I (Kaldor, 1980), is exhausted, causing the continuous increase in the demand for labor, due to the expansion of the activity level, to raise wages at approximately the same pace as labor productivity growth. The growth of wages, in turn, makes it possible to increase the population's standard of living.

Capital accumulation and technical progress are the fundamental sources of growth of labor productivity and population's standard of living. Indeed, technical progress enables, on the one hand, an increase in production efficiency (i.e., that the same goods and services are produced by using a smaller quantity of inputs, in particular labor); and, on the other hand, it leads to the development of increasingly sophisticated products and services, which are products that incorporate a larger and more diversified amount of technical and scientific knowledge. These more complex products are produced by highly skilled workers in companies operating at or near the technological frontier; reason for which these products have higher added-value per unit of labor employed. Thus, technical progress stems, not only from the advancement of the 'state of the art', but also through a process of structural change, in which productive resources and workers are transferred from the activities with lower added-value per worker employed to activities with higher added-value per worker (the more complex sectors).

Capital accumulation is also an important element in the process of the diffusion of technical and scientific knowledge to the whole economy, since a considerable part of this knowledge is incorporated in machines and equipment, making it impossible to separate the increase of labor productivity that results from the advance of the 'state of the art' from the one that results from a greater "mechanization" of the workforce. As emphasized by Hidalgo (2015), physical capital is nothing more than technical and scientific knowledge embodied in machines and equipment. The relationship between the growth of labor productivity and the capital accumulation effort was pioneered by Kaldor (1957), and it was called a function of technical progress:

$$\hat{y}_t = \alpha_{0,t} + \beta_0 \hat{k}_t \tag{1}$$

being $\hat{y}$ the growth rate of the product per worker in period t; $\alpha_{0,t}$ is the autonomous part of the labor productivity growth in period t, that is, that share of productivity gains that are not directly attributable to the greater 'mechanization' of the labor force; β_0 is a positive parameter that captures the ability of the economy to transform the increment of technical and scientific knowledge in increase of productivity through investment in machines and equipment; $\hat{k}$ is the growth rate of capital per worker in period t.

The constant term of the equation (1) reflects not only that share of the technical progress that is disembodied from machines and equipment (Oreiro, 2016, p. 49), but also, the sophistication and complexity of the productive structure of the economy. As the economy undergoes a structural change, in which productive resources are transferred from the less complex and sophisticated sectors to more complex ones, there will be an increase in labor productivity as a result of the increase in the average sophistication/complexity of the economy.[1]

The available empirical evidence indicates the existence of a positive correlation between the economic complexity index elaborated by Hidalgo (2015) and the per capita income level

[1] Hidalgo (2015, pp. 145-146) defines economic complexity as the combination of the diversity and sophistication of productive activities, which originates from accumulated scientific and technical knowledge.

of a sample of countries.[2] Economic complexity, in turn, seems to be positively associated with the share of the manufacturing industry in GDP. In this context, it is possible to establish a link between the share of the manufacturing industry in GDP and the autonomous part of the function of technical progress. In particular, we can assume that an increase in the share of the manufacturing industry in GDP will result in an increase in growth of labor productivity that is autonomous with respect to the capital accumulation effort. If the autonomous part of technical progress depends on structural change and this, in turn, is strongly correlated with the evolution of the share of the manufacturing industry in the GDP, it is possible to write that:

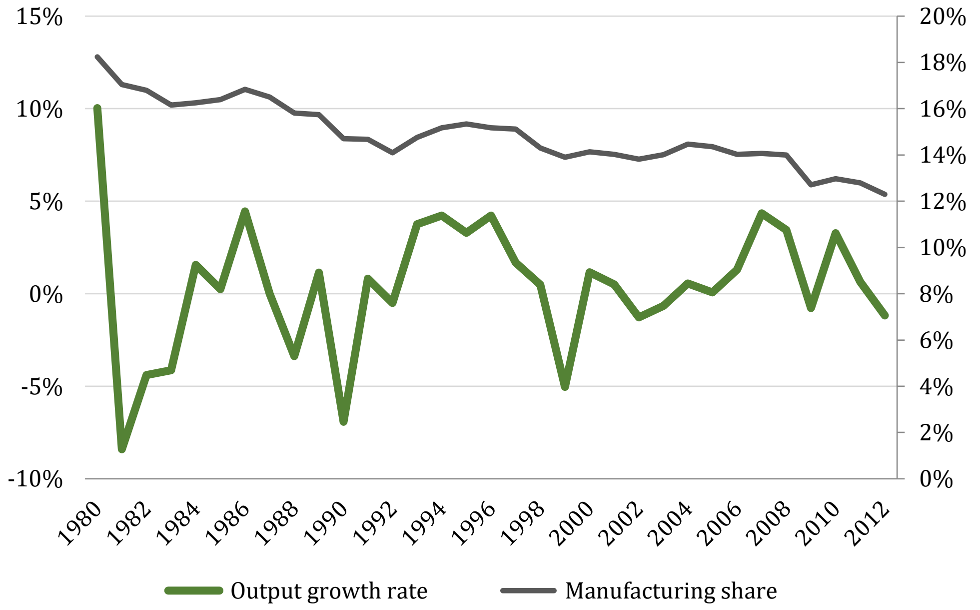
$$\alpha_{0,t} = \delta_0 + \delta_1(h_t - h_{t-1}) \tag{2}$$

where h_t is the share of industry value added in GDP in t. Substituting (2) into (1), we get:

$$\hat{y}_t = \delta_0 + \delta_1(h_t - h_{t-1}) + \beta_0\hat{k}_t \tag{3}$$

Equation (3) is the final form of the technical progress function in which the rate of labor productivity growth depends on the growth rate of the stock of capital per worker, and the change in the share of the manufacturing industry in GDP. We can see that productivity growth is affected both by the rate of capital accumulation, and therefore by investment expenditures, and by the evolution of the composition of the productive structure.

Figure 1 – *Manufacturing share in GDP and growth rate of real GDP in the Brazilian economy, 1980-2012*



Notes: left axis: real GDP growth rate; right axis: manufacturing share in GDP. GDP is calculated at 2013 prices. Manufacturing share is calculated at constant prices (see Marconi and Rocha, 2012).
Sources: Ipeadata, available at www.ipeadata.gov.br, and Marconi and Rocha (2012).

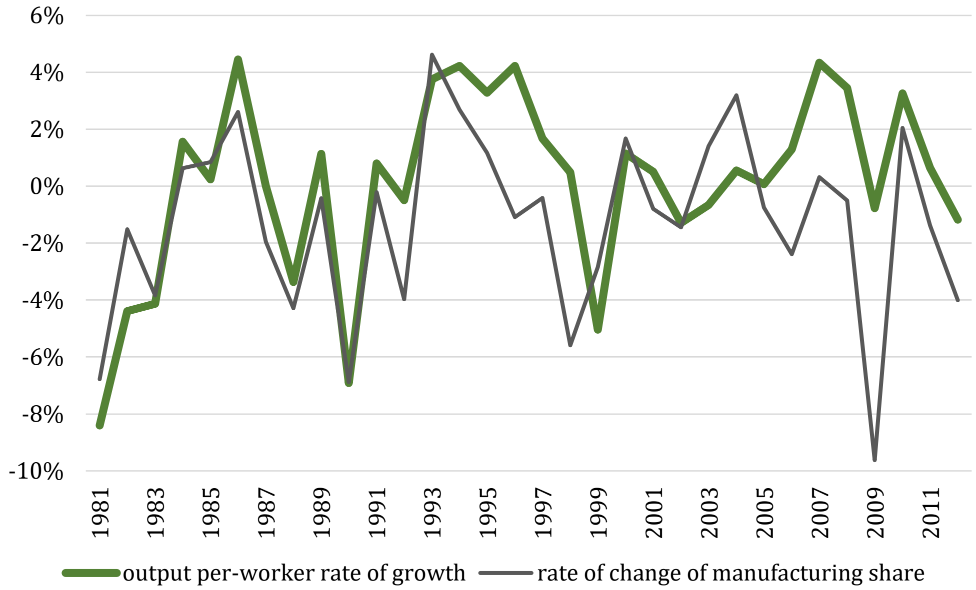
Drawing attention now to the Brazilian case, we can see in figure 1 that, since the beginning of the 1980s, manufacturing as a share of GDP has been decreasing, reason for which

[2] See Gala (2017) for the methodology behind the construction of the index of economic complexity.

the Brazilian economy faced a process of (premature) deindustrialization.[3] This negative structural change was accompanied by a permanent slowdown in the rate of economic growth.

According to the theory presented so far (equation 3), a reduction of the manufacturing share in GDP will be followed by a reduction in the GDP per worker growth rate. This is a strong relation in the case of the Brazilian economy, as we can see in figure 2.

Figure 2 – *GDP per-worker growth rate and rate of change of manufacturing share in GDP for the Brazilian economy, 1981-2012*



Sources: Ipeadata, available at www.ipeadata.gov.br.

2. Balanced growth and capital accumulation

Balanced growth trajectories, in which the proportions among economic aggregates are kept constant over time, have historically been the focus of the Economic Development Theory. This is because such trajectories have the fundamental property of being sustainable over time, so being durable enough to affect the population well-being in a permanent way (Oreiro, 2016). This does not mean that unsustainable growth trajectories are impossible to occur; on the contrary, the historical experience of developed and developing economies has numerous examples of growth trajectories that are unsustainable due to their association with increasing macroeconomic imbalances. Along a balanced growth trajectory, output and capital stock must grow at the same rate in order to keep the product-capital ratio constant. To understand why, let us consider equation (4):

[3] For an analysis of "premature deindustrialization", see Rodrik (2015).

$$Y = \frac{Y}{\bar{Y}}\frac{\bar{Y}}{K}K = u \cdot \sigma \cdot K \quad (4)$$

where Y is the real output level; $\bar{Y}$ is the potential output level, for example the real value of the production of final goods and services that could be obtained if the firms were operating with a normal degree of utilization of productive capacity; K is the real value of the capital stock of the economy; $u = Y/\bar{Y}$; and $\sigma = \bar{Y}/K$ is the productivity of capital, which is, the maximum output that can be obtained with one unit of capital.

Based on equation (4), we can see that the output-capital ratio is equal to the level of capacity utilization multiplied by the productivity of capital. Thus, in order for the output-capital ratio to be stable over time, it is necessary that the level of capacity utilization and the productivity of capital do not have a tendency to increase or decrease over time. The level of capacity utilization is variable, due to business cycles, but fluctuates between 70% and 90% over the long term. The behavior of capital productivity depends on the nature of the technical progress. According to Harrod (1948), technical progress can be classified in three types: (i) *capital intensive,* when the rate of growth of capital stock is higher than the rate of output growth, causing capital productivity to decline over time; (ii) *neutral,* when the rate of growth of capital stock is equal to the rate of output growth, so that the productivity of capital is kept constant over time; (iii) *capital saving,* when the capital stock growth rate is lower than the output growth rate, so that capital productivity is growing gradually.

Empirical evidence for developed countries has indicated the stability of capital productivity in the long run (Thirlwall, 2006). Which is, a neutral technical progress in the sense of Harrod; although these estimates may be biased due to the difficulties in defining the concept of capital. From these findings, we can establish that, in the long term, the growth rate of the real output is approximately equal to the growth rate of the capital stock, in order to maintain the output-capital ratio at a stable level. Thus, the growth rate of output is determined by the growth of capital:[4]

$$g_y = g_k \quad (5)$$

where g_y is the rate of growth of the real value of the production of final goods and services; and g_k is the growth rate of the capital stock.

In turn, the rate of growth of capital stock is given by:

$$g_k = \frac{\Delta K}{K} = \frac{I - \delta K}{K} = \frac{I}{Y}\frac{Y}{K} - \delta = fu\sigma - \delta \quad (6)$$

where I is the real value of gross fixed capital formation; and δ is the depreciation rate of the capital stock. The equation $f = I/Y$ is the ratio between gross fixed capital formation (in real terms) and the real value of output of final goods and services (i.e. the investment rate), which is expressed by:

$$f = \frac{I}{Y} = \frac{P_I I}{P_Y Y}\frac{P_Y}{P_I} = \frac{INV}{GDP}\frac{1}{\rho} \quad (7)$$

where P_I is the capital goods price index; P_Y is the GDP deflator; $P_I I$ is the nominal value of investment expenses (INV); $P_Y Y$ is the nominal GDP; and P_I/P_Y is the relative price of investment goods.[5]

[4] For the Brazilian economy, Bonelli and Bacha (2013) present empirical evidence showing that the causal relationship is derived from the growth of the capital stock for real product growth.

[5] Bonelli and Bacha (2013) present an equation for the growth of capital stock similar to equation (8) above, except for the use of the savings rate instead of the investment rate. From the national accounts point of view, there is no

Substituting (7) into (6) we get:

$$g_k = \left(\frac{I}{GDP}\right)\left(\frac{1}{\rho}\right)u\sigma - \delta \quad (8)$$

Based on (8), we can conclude that the growth rate of the capital stock is a direct function of the investment rate, the level of capacity utilization, and the productivity of capital; and an inverse function of the relative price of the investment, and of the rate of depreciation of the capital stock.

3. The determinants of the investment rate: a review of the literature

The previous section has shown that along a balanced growth trajectory, the dynamics of the GDP level strongly depend on the rate of capital accumulation, which directly depends on the share of the real output that is devoted to gross fixed capital formation, which depends on the investment rate. Regarding the factors that determine the share of real GDP allocated to investment, one of the most accepted theories is the so-called "accelerator hypothesis", according to which entrepreneurs invest to adjust the size of productive capacity to expected sales growth. Firms, however, have a desired level of idle capacity either as a defensive strategy against the entry of new competitors or as a mechanism to meet an unexpected increase in sales without losing market shares to competitors (Steindl, 1952). Therefore, the share of investment in GDP will depend on the degree of utilization of productive capacity: the larger the scale, greater the need for firms to invest in order to restore the desired level of idle capacity. The dependence of investment on the degree of utilization of productive capacity is present in Rowthorn (1981), and the investment desired by firms not only depends on the degree of utilization of productive capacity, but also on the rate of profit, in line with Kalecki (1971) and Robinson (1962). The investment function of Rowthorn (1981) is given by:

$$\frac{I}{Y} = I(r,u); \quad I_1 \equiv \frac{\partial I}{\partial r} > 0\ ;\ I_2 \equiv \frac{\partial I}{\partial r} > 0 \quad (9)$$

The rate of profit appears as an explanatory variable in the investment function as a proxy for the expected profitability of new investment projects. In conditions of strong uncertainty, economic agents create their expectations based on conventions, particularly on the idea that the current business situation is a valuable guide for the future, unless they have reasons to expect changes (Keynes, 1936). Thus, the current rate of profit will play a crucial role in shaping expectations about the profitability of new investment projects.

The profit rate is equal to the share of profits in income times the degree of utilization of productive capacity, times the productivity of capital. Considering the productivity of capital as a constant (assuming a neutral technical progress in Harrod's sense), the dynamics of investment will depend on the relationship between the degree of utilization of productive capacity and the share of profits in income. If an increase in this share is associated with an increase in the utilization of productive capacity, then the profit rate will necessarily increase,

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difference between the version used by Bonelli and Bacha (2013) and the version we are using in this article, since aggregate investment is, by definition, equal to aggregate savings. There is, however, an important theoretical divergence with regard to causality. In a Keynesian perspective, investment determines savings, so the correct specification of the capital accumulation equation must use the investment rate, not the savings rate, as the explanatory variable. In the neoclassical perspective, as adopted by Bonelli and Bacha (2013), the savings determine the investment, which is why these authors use the savings rate as explanatory variable (see Carvalho, 2015).

thus inducing an increase in the share of investment in output. In this case, we say that a profit-led accumulation regime prevails in the economy. Differently, if an increase in the share of profits in income is associated with a reduction in the utilization of productive capacity, the profit rate may be reduced due to the redistribution of income from wages to profits. If the reduction of the profit rate is strong, the I/Y portion may be reduced, characterizing a wage-led regime. Bhaduri and Marglin (1990), who propose the function below, define the conditions for the existence of accumulation regimes driven by profits and wages:

$$\frac{I}{Y} = I(m,u); \quad I_1 \equiv \frac{\partial I}{\partial m} > 0\,; \; I_2 \equiv \frac{\partial I}{\partial u} > 0 \qquad (10)$$

where m is the share of profits in income.

Such specification of the investment function is useful by decomposing the influence of the profit rate over investment into its two components: the share of profits in income and the degree of capacity utilization. It is thus possible to verify separately the role of the functional distribution of income and the degree of utilization on the share of investment in output. When the sensitivity of I/Y to a varying profit share in income is relatively high, and/or the sensitivity of I/Y to variations in the degree of utilization of productive capacity is relatively low, then the economy will be more likely to have a profit-led accumulation regime. Otherwise, it will be prone to a wage-led regime.

Differently, the incorporation of financial variables into the investment function was done, among others, by Taylor and O'Connell (1985), who developed a model that formalized aspects of Minsky's (1982) financial instability hypothesis. Based on this model, the I/Y plot can be presented by:

$$\frac{I}{Y} = \beta_1 + \beta_2(r + \xi - i); \quad \beta_1 > 0\,; \; \beta_2 > 0 \qquad (11)$$

being r the rate of profit; ξ the confidence level of the entrepreneurs; and i the real interest rate.

Based on (11), the share of investment in output is negatively influenced by the interest rate, which represents the opportunity cost of investment in fixed capital. An increase in this rate reduces investment as the present value of the expected cash flow of new investment projects decreases, thus reducing the demand price of capital equipment.

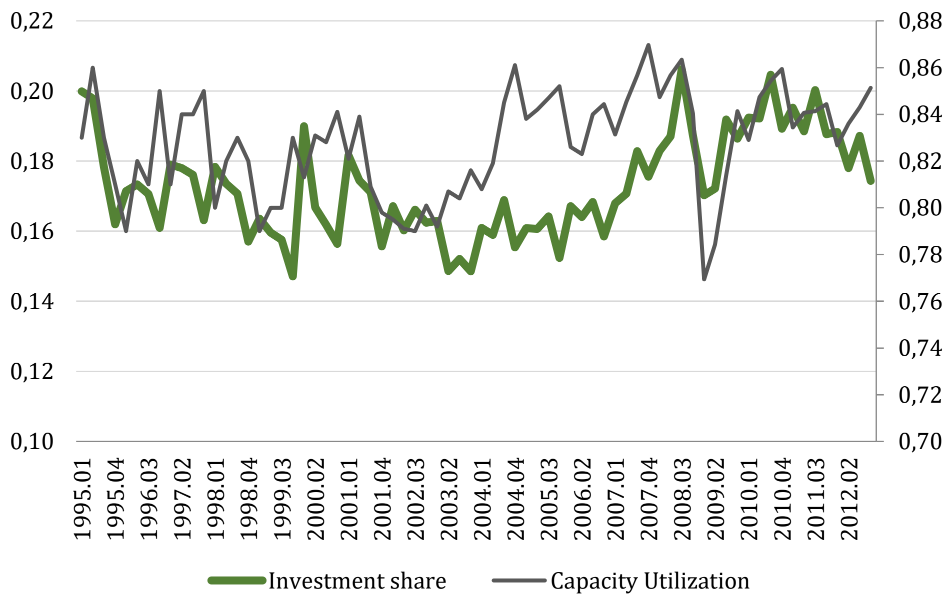
Literature, such as Oreiro and Araújo (2013), that seeks to explore the possible relations between the real exchange rate and investment decisions has recently been developed. For these authors, the real exchange rate presents a non-linear relation with the investment desired by the entrepreneurs, similar to an inverted U. The authors justify this relationship with the following argument: for low levels of the real exchange rate, currency depreciation stimulates investment since it allows an increase in the market power of domestic firms, and therefore an increase in profit margins and in the share of profits in income. The increase in profit margins, in turn, will lead to a higher rate of capital accumulation. As a share of the demand for capital is met through imports, a very high exchange rate could discourage investment decisions. This is because raising the profit margins of domestic firms may not be enough to offset rising costs of imported capital goods. A very high exchange rate can thus cause the supply price of capital goods to exceed its demand price, discouraging investment. The specification of the investment function based on Oreiro and Araújo (2013) is:

$$\frac{I}{Y} = \alpha_0 + \alpha_1 \cdot h + \alpha_2 \cdot u + \alpha_3 \cdot \theta - \alpha_4 \cdot \theta^2 - \alpha_5 \cdot i \qquad (12)$$

where θ is the real exchange rate.

In figure 3, we can see the trend of investment rate and capacity utilization in Brazil in the period between 1995 and 2012.[6] From the first quarter of 1995 to the first quarter of 2003, the investment rate fluctuated between 16% and 18% of GDP. In the same period, capacity utilization fluctuated around 82% of full capacity. From 2003 on, we can observe a clear increase in the average level of capacity utilization and also an increase in the investment share. Indeed, from 2003 to 2012, investment share fluctuated between 18% and 20% and capacity utilization fluctuated between 82% to 85% of full capacity. So, there is some empirical basis for assuming an accelerator effect in the Brazilian economy.

Figure 3 – *Investment share and capacity utilization in the Brazilian economy, quarterly data, 1995.01-2012.02*



Source: Ipeadata, available at www.ipeadata.gov.br.

4. Structural change, exchange rate and the technological gap: explaining the deindustrialization of the Brazilian economy

In section 1 we showed that the evolution of the manufacturing industry share in GDP is a determinant of the labor productivity growth rate and, therefore, of the rate of economic growth. In this context, industrialization, which is understood as a sustained increase in the share of manufacturing industry in GDP, is the engine of long-term growth (Thirlwall, 2002). The emphasis on industrialization as the engine of growth is in agreement with the Kaldorian and structuralist literature, which emphasizes the fundamental role of industry as the locus of

[6] There is no available data for capacity utilization before 1995.

increasing returns and dynamic economies of scale. The dynamics of the share of the manufacturing industry is influenced by price and by non-price factors. With regard to price competitiveness, an overvalued exchange rate, so below the level that makes the foreign firms operating with world-class technology competitive on the international market, would lead to a progressive reduction of the manufacturing share in GDP. As this situation induces an increasing transfer of productive activities abroad, it would lead to the substitution of domestic production for imports. We will call this the level of industrial equilibrium real exchange rate (Bresser-Pereira et al., 2014). Thus, a situation of exchange rate overvaluation is associated with a negative structural change in the economy, which may be termed premature deindustrialization. An undervalued exchange rate, that is, above the level of industrial equilibrium, would have the opposite effect. It would induce a transfer of productive activities from abroad to the domestic economy, increasing the manufacturing share.

Focusing the attention to non-price competitiveness, a key feature of developing countries is that they are far from the technological frontier. This technological gap has a negative effect on the non-price competitiveness of developing countries' manufacturing industries, as they produce manufactured goods that are of inferior quality and/or of less technological intensity when compared to manufactured goods in developed countries (Verspagen, 1993). The existence of this gap is a key factor in reducing the competitiveness of the manufacturing industry in developing countries, thereby contributing to a reduction in its share in GDP.

On the basis of this discussion, we can assume that the dynamics of the share of the manufacturing industry in the GDP in the case of developing countries is given by:

$$h_t = h_{t-1} + \beta_3\left(\theta - \theta^i\right)_{t-1} - \beta_4(G_{t-1} - 1) \tag{13}$$

where θ is the real exchange rate; θ^i is the exchange rate of industrial equilibrium; G is the technological gap; $0 < \beta_3 < 1$ is a parameter that represents the discretionary policies that directly affect the development of the industrial sector (for example, the level of import tariffs); and β_4 is a coefficient that captures the sensitivity of the productive structure to the technological gap.

It can be seen from equation (13) that for those economies operating at the technological frontier, the level of the real exchange rate, for which the manufacturing share is constant over time, is equal to the industrial equilibrium level.[7] However, if the economy is far from the technological frontier, the share of the manufacturing industry in GDP can only increase over time if the real exchange rate is above the industrial equilibrium level. Substituting (13) into (3) we obtain the final format of the technical progress function:

$$\hat{y}_t = \delta_0 + \delta_1\left[\beta_3\left(\theta - \theta^i\right)_{t-1} - \beta_4(G_{t-1} - 1)\right] + \beta_0\hat{k}_t \tag{14}$$

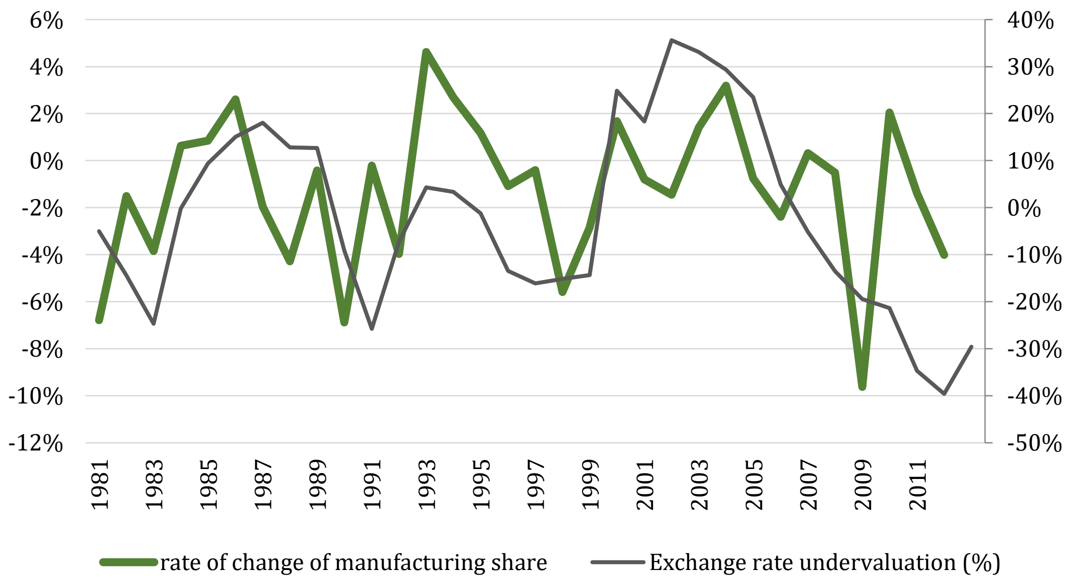
Thus, the growth rate of labor productivity in a developing economy depends on the rate of capital accumulation per worker, the level of exchange rate undervaluation, measured by the difference between the real exchange rate and the level of industrial equilibrium, and the technological gap.

Figure 4 presents the relation between the rate of change in the manufacturing share in GDP and the rate of exchange rate undervaluation for the Brazilian economy between 1981

[7] If we assume $h_t = h_{t-1}$ in equation (13), the following expression will be obtained: $\theta = \theta^i + (\beta_4/\beta_3)(G - 1)$, with G = 1 (assuming that the technological frontier does not move), we have $\theta = \theta^i$, so that the level of the share of manufacturing in GDP is constant.

and 2012. As predicted by the theory presented so far – see equation (13) – increases in the manufacturing share in GDP are generally associated with an undervalued exchange rate, except for the period 1993-1996; and decreases in the manufacturing share are associated with an over-valued exchange rate.

Figure 4 – *Rate of change of manufacturing share in GDP and exchange rate undervaluation (%) for the Brazilian economy, 1981-2012*

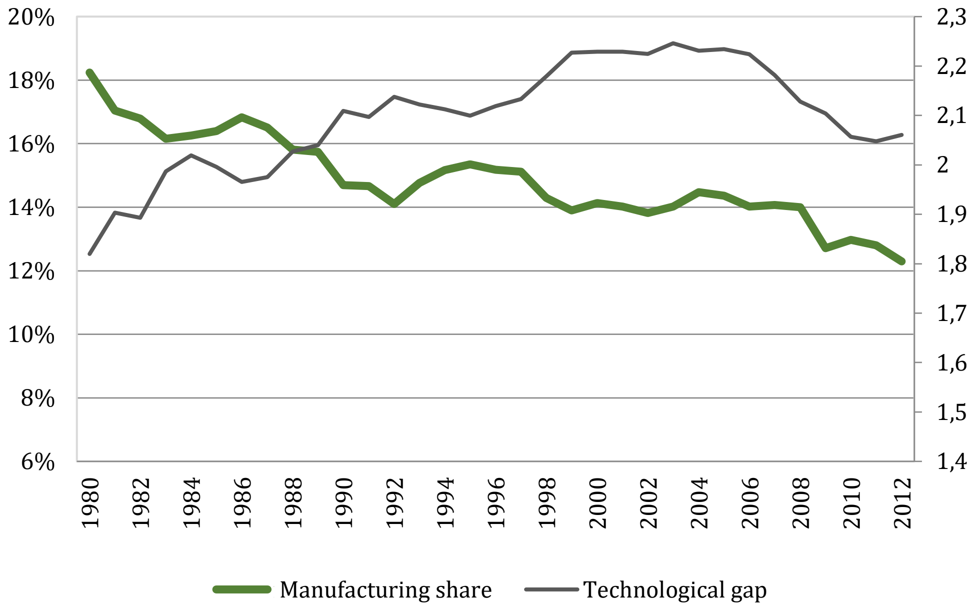


Notes: real exchange rate undervaluation (%) is defined as the difference between the log of real exchange rate for year *t* minus the log of industrial equilibrium exchange rate. Industrial equilibrium exchange rate is assumed to be equal to the average real exchange rate for the period 1980-2012.
Sources: Ipeadata, available at www.ipeadata.gov.br, and Marconi and Rocha (2012).

Regarding the role of non-price competitiveness factors – proxied by the technological gap – over the deindustrialization process of the Brazilian economy, figure 5 shows that the deindustrialization observed from 1980 on was followed by a huge increase in technological gap until 2004. The moderate acceleration of GDP growth after 2004 (see table 1) was responsible for a modest reduction of the technological gap until 2012.

Based on the data for the manufacturing share, the rate of exchange rate undervaluation, and the technological gap, we can infer that the deindustrialization process of the Brazilian economy from 1980 on was the combined result of the trend for exchange rate over-valuation and technological backwardness of the Brazilian manufacturing industry. As technological backwardness is a key feature of all developing countries, deindustrialization could only be avoided by means of an undervalued exchange rate and/or controls over imports. The import substitution industrialization (ISI) development model adopted in Brazil from 1930-1980 was heavily based on high import tariffs, export subsidies and other types of import controls to induce the industrialization of the economy. However, this development model was exhausted at the end of the 1970s due to the very low level of trade openness of the Brazilian economy. A change to an export-led growth industrialization was required in the beginning of the 1980s, which could only be implemented by means of an exchange rate policy, designed to produce an undervalued real exchange rate. The concern with inflation stabilization, however, not only prevented the adoption of such a policy, but also made policy makers prone to use an exchange rate anchor in the beginning of the 1990s in order to fight inflation. High inflation disappeared after 1995 and caused a trend for exchange rate overvaluation that accelerated the deindustrialization process of the Brazilian economy.

Figure 5 –*Manufacturing share in output and technological gap of the Brazilian economy, 1980-2012*



Notes: Manufacturing share is measured on left axis and technological gap is measured on right axis. Technological gap is calculated as the log of the ratio between output per worker in the United States and output per worker in Brazil.
Source: Ipeadata, available at www.ipeadata.gov.br.

5. Dynamics of capital accumulation in Brazil (1980-2012)

There is a consensus among Brazilian economists that the high growth that Brazil experienced since the post-World War Second ended in the early 1980s, leading to what was called "the lost decade". The collapse of the pace of economic growth persisted even after price stabilization in 1994. For the whole period between 1980 and 2012, the Brazilian economy showed an average growth of real GDP of 2.73% per year, characterizing a semi-stagnation growth regime. In the period between 1980 and 1994, previous to inflation stabilization achieved through the "Plano Real", real GDP growth was only 2.32% per year. After inflation stabilization, in the period between 1995 and 2012, growth accelerated to 3.04%. The end of high inflation in Brazil was not followed by a return to high growth rates observed until the end of the 1970s.

In section 2 we have seen that along a balanced growth path, real GDP and capital stock should grow at the same rate. These results are consistent with those of Bonelli and Bacha (2013) for the period 1947-2010. Thus, the pace of growth of the Brazilian economy seems to be determined by the pace of capital accumulation.[8]

Table 1 – *Real GDP growth of the Brazilian economy, 1980-2012*

Period	Real GDP growth
1980-1984	1.51%
1985-1989	4.26%
1990-1994	1.17%
1995-1999	2.01%
2000-2004	2.97%
2005-2009	3.52%
2010-2012	3.66%
1980-2012	2.73%

Notes: GDP calculated at 2013 prices.
Source: Ipeadata, available at www.ipeadata.gov.br.

In this context, we use equation (8) presented in section 2 to calculate the growth rate of the capital stock of the Brazilian economy in the period 1980-2012. The rate of investment at constant prices, f, was obtained using data on gross fixed capital formation and GDP at current prices, together with the variable "relative price of investment", obtained from the Ipeadata database. The relative price of the investment, ρ, was calculated as the ratio between the implicit capital goods deflator and the GDP deflator. Capital productivity, σ, was calculated as the ratio between GDP and the capital stock of the economy, split by the degree of utilization of productive capacity in order to separate the variations in the product-capital ratio that result from fluctuations in the level of economic activity from those arising from technical progress. In the construction of this variable for the period 1980-2007, we used the series calculated by Alvim et al. (2006; 2007); whereas for 2008-2012 the calculation was done using the method used by Bonelli and Bacha (2013), based on Morandi and Reis (2004). The depreciation rate of capital stock, δ, was assumed 3.9% per year, based on Bonelli and Bacha (2013). The series of the utilization of productive capacity, u, was obtained from the Getulio Vargas Foundation (FGV) database, available at https://portal.fgv.br/en. The evolution of the capital growth rate, the investment rate, the relative price of investment and the productivity of capital for the period 1980-2012 can be seen in table 2.

[8] For an empirical analysis of this hypothesis for the Brazilian economy in the period 1980-2012, see Appendix 1.

Table 2 – *Dynamics of capital accumulation in Brazil, 1980-2012*

Period	Growth rate of capital stock	Investment rate at current prices	Relative price of investment goods	Capital productivity
1980-1984	7.68%	21.26%	1.11	0.72
1985-1989	6.93%	22.93%	1.30	0.63
1990-1994	4.28%	20.35%	1.33	0.63
1995-1999	3.43%	17.19%	1.08	0.57
2000-2004	2.62%	17.04%	1.17	0.57
2005-2009	3.34%	17.81%	1.17	0.58
2010-2012	4.33%	19.13%	1.10	N.A
Δ(%) 1980-2012	–43.53%	–10.42%	+1.53%	–19.93%

Notes: the degree of utilization of productive capacity increased by 9.53% in the period 1980-2012, acting as an attenuating force of the movement to reduce the pace of capital accumulation in the Brazilian economy.

According to the data in table 2, we can see the occurrence of a very strong reduction of the growth rate of the capital stock in the Brazilian economy since the beginning of the 1990s. In the 1980s, capital stock grew at an average rate of 7.30% per year; in the 1990s, the growth rate of the capital stock decreases to 3.85% per year; we can see a reduction of 47.22% in the pace of capital accumulation. In the 2000s, the slowdown in the pace of capital accumulation continued, with the average growth rate of capital stock dropping to 2.98% per year, and a reduction of 22.59% compared to the average recorded in the previous decade. Only in the period 2010-2012 the pace of capital accumulation accelerated again, increasing to 4.33% per year. The data in table 2 also gives understanding to the most immediate reasons for the decline in the pace of capital accumulation. In the period 1980-2012 we saw a strong reduction of the investment rate accompanied by a very significant reduction of capital productivity. The relative price of investment goods remained stable in the period with minor influence on the path of capital accumulation. The investment rate fell from 22.09% in the period 1980-1989, to 18.77% in the period 1990-1999. The reduction of the investment rate continued in 2000-2009, when it reached an average value of 17.81%.

6. Empirical determinants of the investment share, labor productivity growth and share of the manufacturing industry

In order to estimate the determinants of the investment share in the Brazilian economy, we used 72 quarterly observations, beginning from the first quarter of 1995 to the fourth quarter of 2012, due to the lack of part of the data from 1980 to 1995. To estimate the determinants of the share of the manufacturing industry in output and of the rate of growth of labor productivity we used 33 annual observations from 1980 to 2012. Table 3 describes the set of variables used and the respective data sources.

Table 3 – *Variables and data sources*

	Description	Format	Data source
Variables used to calculate the investment rate at current prices			
I/Y	Investment share of GDP at current prices	%	Ipeadata
u	Level of capacity utilization in the manufacturing industry – average	%	FGV, *Economic Review*, available at https://portal.fgv.br/en
θ	Effective real exchange rate – Consumer Price Index – imports – index (1995 T1=100), quarterly index calculated by the average of the component months	Index	Ipeadata, available at www.ipeadata.gov.br
R	Real interest rate of the economy, end of the last month of the quarter, calculated using the SELIC nominal interest rate and observed IPCA inflation rate.[9] SELIC Rate is defined as the adjusted average rate of the daily financings determined in the Special System of Settlement and Custody (SELIC) for federal securities.	%	Central Bank of Brazil
i	SELIC nominal interest rate, value of the last month of each quarter	%	Central Bank of Brazil
π	Inflation rate, IPCA, accumulated in 12 months, average value of the quarter	%	IBGE
θ/w	Exchange rate/wage ratio index (average 2010= 100), average value of the quarter	Index	Ipeadata
λ	Emergent Bond Market Index + Brazil-Risk – quarterly average, constructed from daily observation of the quarter considered	Points	JP Morgan
Variables used to estimate the rate of growth of labor productivity			
y	Annual rate of growth of output per worker. Calculated using the GDP growth rate and the growth rate of the employed population (calculations in log)	%	Ipeadata, Penn World Tables
h	Share of value added of the manufacturing industry in GDP	%	Ipeadata
h_{t-1}	Share of the value added of the manufacturing industry in GDP, lagged one period	%	Ipeadata
k	Annual growth rate of the capital stock per worker. Calculated using the capital stock growth rate and the growth rate of the employed population (calculations in log)	%	Ipeadata, Penn World Tables
Variables used to estimate the share of the manufacturing industry			
θ	Real effective exchange rate – IPA-OG-IT – exports-manufacturing-index (average 2010=100).[10] The annual observation was calculated by 12-month average	Index	Ipeadata
θ^i	Industrial equilibrium real exchange rate, calculated by the series of long-term trend of the real exchange rate, θ, estimated by the Hodrick-Prescott Filter	Index	
G_{t-1}	Technological gap, lagged a period. Calculated using the ratio between the log of US per capita income and the log per capita income of Brazil	%	Central Bank of Brazil

On these data, we estimated: (*i*) the correlation matrix between variables; (*ii*) stationary series tests; (*iii*) principal components analysis; (*iv*) estimations of the parameters; and (*v*) diagnostic tests on the coefficients, residuals and stability.

[9] IPCA, in Portuguese, is the abbreviation of the Índice de Preços do Consumidor Amplo, and is measured monthly by IBGE (Statistic Geography Brazilian Institute). It is measured as a reflection of the cost of living of families who have income between 1 and 40 minimum wages, based on 9 metropolitan regions of the country.
[10] IPA-OG-IT is the abbreviation of the Broad Producer Price Index; it measures the average price variations received by domestic producers in the sale of their products.

6.1. Multivariate analysis: the correlation matrix

From the analysis of correlation, we chose the candidate variables that have relevant correlation with the share of investment on output, and/or with the share of the manufacturing industry in output, and/or with the rate of growth of labor productivity in order to compose the possible set of explanatory variables in each statistical model. According to the Cauchy-Schwarz corollary, we adopted numerical criteria to differentiate the degree of correlation and linear dependence between variables, defining the degrees as strong to moderate (thus defining a candidate explanatory variable) if they are greater than 0.3 in absolute terms, and weak (the variable is not a candidate explanatory variable) for values of the Pearson correlation lower than 0.3 in absolute terms.

We report three different correlation matrices: results of the correlation between the variable share of investment and the candidate explanatory variables in level first difference, Δ, in growth rate, %, and in lags, are shown in table 4. Likewise, in tables 5 and 6, we present the correlation results for the rate of growth of labor productivity and the share of the manufacturing industry in output with the candidate variables.

Table 4 – *Correlations between the share of investment on output and possible explanatory variables to be included in the statistical model*

Correlation	I/Y	p-value	Correlation	I/Y	p-value	Correlation	I/Y	p-value
$(I/Y)_{-1}$	0,66	0,00	r	−0,39	0,00	θ	−0,66	0,00
$\%(I/Y)$	0,42	0,00	r_{-1}	−0,40	0,00	$\Delta\theta$	0,02	0,89
$\Delta(I/Y)$	0,41	0,00	r_{-2}	−0,45	0,00	$\%\theta$	−0,01	0,97
u	0,35	0,00	$\%r$	−0,08	0,51	θ^2	−0,62	0,00
u_{-1}	0,44	0,00	Δr	0,01	0,98	θ^2_{-1}	−0,63	0,00
u_{-2}	0,24	0,14	i	−0,52	0,00	$\Delta\theta^2$	0,04	0,77
Δu	−0,09	0,45	i_{-1}	−0,54	0,00	$\%\theta^2$	0,01	0,97
$\%u$	−0,07	0,48	$\%i$	0,08	0,51	θ_{-1}	−0,66	0,00
π	−0,31	0,00	Δi	0,04	0,77	(θ/w)	−0,70	0,00
π_{-1}	−0,31	0,00	λ	−0,50	0,00	$(\theta/w)_{-1}$	−0,72	0,00
$\%\pi$	0,05	0,71	λ_{-1}	−0,56	0,00	$\%(\theta/w)$	0,09	0,47
$\Delta\pi$	0,06	0,63	$\Delta\lambda$	0,12	0,34	$\Delta(\theta/w)$	0,12	0,36

According to table 4, there is: (i) a moderate positive correlation between the share of investment on output, I/Y, and the share of investment on output with a lag, $(I/Y)_{-1}$, the growth rate of the share of investment on output, $\%(I/Y)$, the change in the share of investment on output $\Delta(I/Y)$, and the degree of capacity utilization at a level and with a lag (u e u_{-1}); (ii) moderate negative correlation of the share of investment on output with the inflation rate, π, the nominal interest rate, i, the real interest rate, r, the real exchange rate, θ, the real rate exchange squared, θ^2, and the measure of risk, λ, both in levels and with a lag; (iii) strong negative correlation of the share of investment on output with the real exchange rate ratio with respect to the wage level and with a lag, (θ/w)e$(\theta/w)_{-1}$; (iv) absence and/or no significant linear correlation between candidate variables in first differences and in growth rate, with the share of investment on output.

Table 5 – *Correlations between the share of the manufacturing industry in output and possible explanatory variables to be included in the statistical model*

Correlation	h	p-value	Correlation	h	p-value
h_{t-1}	0,93	0	$(\theta - \theta^i)$	−0,07	0,72
h_{t-2}	0,87	0	θ_{t-1}	0,53	0
θ	0,58	0	$(\theta - \theta^i)_{t-1}$	0,09	0,62
θ^i	0,84	0	$(G_{t-1} - 1)$	−0,57	0

According to table 5, there is: (i) a strong positive correlation between the share of the manufacturing industry in output, itself (lagged in one and two periods), and the industrial equilibrium real exchange rate, which is not lagged; (ii) moderate negative correlation between the share of the manufacturing industry in output with the technological gap variable lagged one period minus one; (iii) a moderate positive correlation between the share of the manufacturing industry in output with the effective real exchange rate variable, not lagged and deferred over a period; (iv) absence and/or there is no significant linear correlation between the share of the manufacturing industry in output with the difference between the real effective exchange rate and the industrial equilibrium real exchange rate, without lag and with a lag.

Table 6 – *Correlations between the labor productivity growth rate and possible explanatory variables to be included in the statistical model*

Correlation	y	p-value	Correlation	y	p-value
y_{t-1}	0.01	0.94	k	0.35	0.047
h	−0.17	0.34	k_{t-1}	−0.48	0.00
Δh	0.72	0.00	k_{t-2}	−0.24	0.19

According to table 6, there is: (i) a strong positive correlation between the labor productivity growth rate and the change in the share of the manufacturing industry in output; (ii) moderate positive correlation between labor productivity growth rate and the growth rate of capital stock per worker; (iii) a moderate negative correlation between the labor productivity growth rate and the growth rate of capital stock per worker, which lags behind in a period; (iv) absence and/or there is no significant linear correlation between the rate of growth of labor productivity, itself lagged in one period, with the growth rate of capital stock per worker, lagged in two periods and with the share of manufacturing industry in output, it is not lagging behind. In order to compose the econometric model, in each function specification, variables that have, over the period considered, moderate or strong (positive or negative sign) correlation were chosen.

6.2. Stationary tests

Next, we determine the order of integration of the candidate series using the Augmented Dickey-Fuller test(ADF).[11] Under the null hypothesis, H_0, the time series tested has a unit root. The results of the ADF tests, using the modified Schwarz criterion (MSIC), are shown in table 7.

[11] The general equation of the ADF test is: $\Delta y_t = \alpha + \beta \cdot t + \gamma \cdot y_{t-1} + \sum_{i=1}^{p-1} \delta_i \cdot \Delta_{t-i} + \varepsilon_i$. There is sensitivity to the presence of deterministic regressors, such as an intercept term, α, or a deterministic time trend, β. Strategically, we estimate stationarity tests without trend and intercept, with trend and intercept, and with intercept only.

Table 7 – *Results of the ADF unit root tests*

Variables	Equation	Lags	T	1%	5%	10%	Prob.	H_0	Integration
Function of the investment share in output									
(I/Y)	I	4	−2.61	−3.53	−2.91	−2.59	0.09	R	I(0)
$(I/Y)_{-1}$	S T/I	5	−1.62	−2.60	−1.95	−1.61	0.10	R	I(0)
$\%(I/Y)$	S T/I	0	−12.72	−2.60	−1.95	−1.61	0	R	I(0)
$\Delta(I/Y)$	S T/I	0	−12.52	−2.60	−1.95	−1.61	0	R	I(0)
u	I/T	0	−4.51	−4.09	−3.47	−3.16	0	R	I(0)
u_{-1}	I/T	0	−4.49	−4.09	−3.47	−3.16	0	R	I(0)
$\%u$	S T/I	0	−10.68	−2.60	−1.95	−1.61	0	R	I(0)
θ	I	2	−1.43	−3.53	−2.91	−2.59	0.58	NR	I(1)
θ_{-1}	S T/I	2	−0.38	−2.60	−1.95	−1.61	0.54	NR	I(1)
$\Delta\theta$	S T/I	0	−6.83	−2.60	−1.95	−1.61	0	R	I(0)
$\%\theta$	S T/I	0	−7.03	−2.60	−1.95	−1.61	0	R	I(0)
θ^2	I	2	−1.43	−3.53	−2.91	−2.59	0.56	NR	I(1)
θ^2_{-1}	S T/I	2	−0.64	−2.60	−1.95	−1.61	0.44	NR	I(1)
$\Delta\theta^2$	S T/I	0	−6.61	−2.60	−1.95	−1.61	0	R	I(0)
$\%\theta^2$	S T/I	0	−7.03	−2.60	−1.95	−1.61	0	R	I(0)
π	T/I	0	−6.23	−4.09	−3.47	−3.16	0	R	I(0)
π_{-1}	T/I	0	−6.23	−4.09	−3.47	−3.16	0	R	I(0)
$\%\pi$	S T/I	0	−10.14	−4.09	−3.47	−3.16	0	R	I(0)
R	T/I	1	−5.79	−4.09	−3.47	−3.16	0	R	I(0)
R_{-1}	T/I	1	−4.03	−4.09	−3.47	−3.16	0	R	I(0)
$\%R$	S T/I	0	−9.33	−2.60	−1.95	−1.61	0	R	I(0)
i	T/I	0	−4.60	−4.09	−3.47	−3.16	0	R	I(0)
i_{-1}	T/I	0	−3.57	−4.09	−3.47	−3.16	0.04	R	I(0)
$\%i$	S T/I	0	−9.70	−2.60	−1.95	−1.61	0	R	I(0)
θ/w	T/I	4	−4.21	−4.09	−3.47	−3.16	0	R	I(0)
$(\theta/w)_{-1}$	T/I	4	−4.24	−4.09	−3.47	−3.16	0	R	I(0)
$\Delta(\theta/w)$	S T/I	0	−7.04	−2.60	−1.95	−1.61	0	R	I(0)
$\%(\theta/w)$	S T/I	1	−1.92	−2.60	−1.95	−1.61	0.04	R	I(0)
Λ	S T/I	0	−1.79	−2.60	−1.95	−1.61	0.07	R	I(0)
λ_{-1}	S T/I	0	−1.59	−2.60	−1.95	−1.61	0.09	R	I(0)
$\%\lambda$	S T/I	0	−6.85	−2.60	−1.95	−1.61	0	R	I(0)
Function of the manufacturing share in GDP									
Variables	**Equation**	**Lags**	**T**	**1%**	**5%**	**10%**	**Prob.**	H_0	**Integration**
h	S T/I	7	−2.37	−3.53	−2.91	−2.59	0.02	R	I(0)
h_{t-1}	S T/I	7	−2.21	−2.60	−1.95	−1.61	0.03	R	I(0)
h_{t-2}	S T/I	0	−12.72	−2.60	−1.95	−1.61	0	R	I(0)
θ	I	3	−2.60	−3.53	−2.91	−2.59	0.10	R	I(0)
θ^i	I	2	−2.69	−3.53	−2.91	−2.59	0.09	R	I(0)
θ_{t-1}	S T/I	10	−1.67	−2.60	−1.95	−1.61	0.09	R	I(0)
${\theta^i}_{t-1}$	T/I	10	−0.89	−2.60	−1.95	−1.61	0.09	R	I(0)
$(\theta - \theta^i)$	S T/I	10 M	−3.44	−2.60	−1.95	−1.61	0	R	I(0)
$(\theta - \theta^i)_{t-1}$	S T/I	10	−3.29	−2.60	−1.95	−1,61	0	R	I(0)
$(G_{t-1} - 1)$	I/T	10	−3.51	−4.28	−3.56	−3,21	0,04	R	I(0)
Function of the growth rate of output per worker									
Variables	**Equation**	**Lags**	**T**	**1%**	**5%**	**10%**	**Prob.**	H_0	**Integration**
y	S T/I	8	−2.73	−2.60	−1.95	−1.61	0.00	R	I(0)
y_{t-1}	S T/I	8	−2.74	−2.60	−1.95	−1.61	0.00	R	I(0)
h	S T/I	7	−2.37	−3.53	−2.91	−2.59	0.02	R	I(0)
h_{t-1}	S T/I	7	−2.21	−2.60	−1.95	−1.61	0.03	R	I(0)
Δh	S T/I	7	−5.39	−2.60	−1.95	−1.61	0.03	R	I(0)
k	S T/I	6	−1.68	−2.60	−1.95	−1.61	0.09	R	I(0)
k_{t-1}	S T/I	6	−1.69	−2.60	−1.95	−1.61	0.09	R	I(0)
k_{t-2}	S T/I	7	−1.69	−2.60	−1.95	−1.61	0.09	R	I(0)

Notes: NR = no reject, R = reject, I/T = intercept and trend, I = intercept, S T/I = no intercept and trend.

In the quarterly series, the hypothesis of unit root (not stationarity) cannot be rejected for the series (at levels) of the real exchange rate and real exchange rate squared, at levels and with a lag, with statistical significance of 1%. These series become stationary by differentiating them once, or taking them in growth rate. Capacity utilization, the investment share on output, the inflation rate, the real interest rate, the nominal interest rate, the exchange rate/wage ratio and sovereign risk measure, in levels, in growth rates or with a lag, can be considered as stationary, at a significance level between 1% and 10%. In the annual series, the levels, with a lag or differentiating, are all considered as stationary, at significance levels between 1% and 10% .

6.3. Principal components analysis

Next, in order to reduce the number of explanatory variables, we applied the principal component variance analysis method. The method shows the main variables that explain most of the original variability (variance) using a relatively small number of k components, among the total set of p components, to describe the behavior of the dependent variable. The principal components of a set of variables are obtained by calculating the *eigenvalue* decomposition of the observed covariance matrix.[12] The eigenvalues[13] ordered from largest to smallest identify candidate variables and that can be inserted into the model. The summary results of principal components ordered by eigenvalues, with the individual and accumulated proportions of variance explained for the rate of investment on product, the share of the manufacturing industry in the product, and the rate of productivity growth, are presented in Appendix, respectively in tables A2, A3, and A4.

Of the 58 candidate variables to explain the variance of the investment share on output, in first difference, in lagged and in growth rate, 10 have eigenvalues above 1. To explain the variance of the share of the manufacturing industry in output, of the 9 candidate variables, in the level, difference and lagged, 4 have eigenvalues above 1. And to explain the variance of rate of growth of labor productivity, of the 7 candidate variables, in the level, difference and lagged, 3 have eigenvalues above 1.

Looking at table A3, of the total variance of the investment share we find that (i) 28.23% is explained by the investment share on output itself; (ii) 17.51% is explained by the share of investment on output, which lags behind in a period; (iii) 10.67% is explained by the degree of capacity utilization; (iv) 9.23% is explained by the degree of capacity utilization, lagged in one period; (v) 7% is explained by sovereign risk (Embi+); (vi) 5.45% is explained by sovereign risk, lagged in one period; (vii) 4.71% is explained by the exchange rate/wage ratio; (viii) 3.69% is explained by the exchange rate/wage ratio, squared; (ix) 3.1% is explained by the real interest rate; (x) 1.85% is explained by the real interest rate, lagged in one period. Added to the proportions of the sample variance of each main component, we can conclude that ten components explain 91.44% of the sample variance of the investment rate on the product.

Of the sample variance of the investment rate on product, we find that: (i) 65.64% is explained by variables originating from the statistical sample of the share of investment on output(45.74%), and the degree of capacity utilization (19.9%), both variables in level and with

[12]For mathematical details of the method, see Johnson and Wichern (2002, chapter 8).
[13]Autovalues, or the characteristic vector of the linear transformation, is a non-null vector that does not modify the original direction when this linear transformation is applied, $T(\boldsymbol{v}) = \lambda \cdot \boldsymbol{v}$. Where λ is the scalar called autovalue or *eigenvalue*, characteristic vector or characteristic root associated with the autovector $\boldsymbol{v}$.

a lag; (ii) 12.45% is explained by the sovereign risk variable in levels (7%), and with a lag (5.45%); (iii) 8.40% is explained by the variable exchange rate/wage in level (4.71%) and squared (3.10%); and (iv) 4.95% is explained by the variable real interest rate in level (4.71%) and lagged by a period (1.85%).

Thus, the correlation matrix, the stationarity tests and the principal component analysis suggest to reduce the number of components to explain the behavior of the share of investment on output. In particular, the variables share of investment on output, the degree of capacity utilization, the risk premium measure, the exchange rate/wage ratio, and the real interest rate, are the principal components to explain the variability of the share of investment on output. Moreover, although it belongs to the set of non-disposable principal components, the exchange rate/wage relation and the real interest rate explains a very small proportion (less than 5% per component) of the behavior of the share of investment on output.

Looking at table A4, of the total variance of the share of manufacturing industry in output, we find that: (i) 37.38% is explained by the share of the manufacturing industry in output; (ii) 23.31% is explained by the share of the manufacturing industry in output lagged a period; (iii) 13% is explained by the technological gap lagged one period, minus one; (iv) 11.56% is explained by the real exchange rate, lagged in one period; and (v) 4.44% is explained by the industrial equilibrium real exchange rate. Adding up the proportions of the sample variance of each principal component, we can conclude that four components explain 90.11% of the share of the manufacturing industry in output. The correlation matrix, the stationarity test and the principal component analysis, indicate to reduce the number of components to explain the behavior of the manufacturing industry's share in output. The share of the manufacturing industry in output, the technological gap minus one, and the real exchange rate, all lagged in a period, are major components to explain the variability of the share of the manufacturing industry in output. In addition, although it belongs to the set of non-disposable main components, we insert in the specification the industrial equilibrium exchange rate, θ^{i}; or the difference between the real exchange rate and the industrial equilibrium exchange rate, $\left(\theta - \theta^{i}\right)$; or the real exchange rate not lagged.

Finally, looking at table A4, of the labor productivity growth rate total variance, we find that: (i) 39.63% is explained by the change in the share of the manufacturing industry in output; (ii) 20.82% is explained by the rate of growth of capital per worker, without lags; (iii) 14.82% is explained by the growth rate of capital per worker, which lags behind in one period. Adding up the proportions of the sample variance of each principal component, we conclude that three components explain 75.27% of the rate of growth of labor productivity. Therefore, we conclude for a reduction in the number of components to explain the behavior of the rate growth of labor productivity, using only the variation of the share of the manufacturing industry, and the rate of growth of capital per worker, with or without lags, or a combination of both.

6.4. Estimation of the investment equation, the rate of growth of labor productivity, and the share of the manufacturing industry in output

As a strategy, we used several combinations of candidate variables to estimate the role of investment rate on output, the rate of growth of output per worker, and the share of manufacturing industry in output. In order to estimate the parameters of the functions, we used the method of ordinary least squares (OLS), conjugated with autoregressive processes

(AR), moving average (MA), autoregressive moving average (ARMA), and autoregressive integrated moving average (ARIMA) with maximum likelihood estimation.[14] We decided to elaborate the outliers test by the Grubbs criterion and, in this way, we set up a set of dummies variables, in certain quarters, for the function of the investment share, and in certain years, for the equations for the rate of growth of labor productivity and the share of the manufacturing industry in output.[15] From convergent iterations, we found the following econometrically interesting functions:

$$\widehat{(I/Y)}_t = 0{,}669797 \cdot (I/Y)_{t-1} + 0{,}090142 \cdot u_t - 0{,}000151 \cdot (\theta/w)_{t-1} + 0{,}0000003 \cdot (\theta/w)_t^2 - 0{,}00000423 \cdot \lambda_{t-1} + 0{,}028596 \cdot \text{D94} - 0{,}497374 \cdot \varepsilon_{t-1} \quad (15)$$

$$\hat{y}_t = 5{,}1163 \cdot \Delta h + 0{,}545852 \cdot k_t + 0{,}4635 \cdot \varepsilon_{t-1} \quad (16)$$

$$\hat{h}_t = 0{,}86236 \cdot h_{t-1} + 0{,}000068 \cdot \theta_{t-1} - 0.08999 \cdot (G_{t-1} - 1) + \varepsilon_t \quad (17)$$

The main results are reported in table 8 for the share of investment on output, in table 9 for the rate of growth of output per worker, and in table 10 for the share of the manufacturing industry in output.

Table 8 – *Estimated model for the share of investment on output*

Variable	Coefficient	Standard error	t	Prob.	I.C. 95%		I.C. 99%	
					Bottom	Upper	Bottom	Upper
$(I/Y)_{t-1}$	0.669797	0.074659	8.97	0.00	0.521	0.819	0.471	0.868
u_t	0.090142	0.018548	4.86	0.00	0.053	0.127	0.040	0.139
$(\theta/w)_{t-1}$	–0.000151	4.54E-05	–3.32	0.00	–0.0002	–6.00E-05	–0.0002	–3.0E-05
$(\theta/w)_t^2$	3.09E-07	1.26E-07	2.45	0.02	5.7E-08	5.60E-07	–2.5E-08	6.4E-07
λ_{t-1}	–4.23E-06	2.46E-06	–1.72	0.09	–9.1E-06	6.85E-07	–1.1E-05	2.3E-06
D94	0.028596	0.007338	3.89	0.00	0.014	0.043264	0.009	0.048
MA(1)	–0.497374	0.135106	–3.68	0.00	–0.76	–0.227	–0.856	–0.138
SIGMASQ	6.22E-05	1.22E-05	5.095	0.00	3.7E-05	8.66E-05	2.9E-05	9.4E-05

Notes: $R^2 = 0{,}69, \bar{R}^2 = 0{,}65$; Durbin-Watson: 1.99; root of the inverted moving average equal to 0.497; F-statistic = 79.13; Prob(F) = 0.00; I.C. is the confidence interval. Statistics based on a sample of 79 observations (70 adjusted observations).

[14] In order to estimate the determinants of the investment share in the Brazilian economy, we used 72 quarterly observations, from the first quarter of 1995 to the fourth quarter of 2012. To estimate the determinants of the share of the manufacturing industry in output and of the rate of growth of labor productivity, we used 33 annual observations from 1980 to 2012. In this case, the VAR method and impulse response functions are not applied because the times series are different.

[15] Since lagged and non-lagged variables were combined to explain the behavior of the investment share, of the share of the manufacturing industry in output, and of the labor productivity growth rate, the roots of the polynomial characteristic were verified and the condition of invertibility of the ARMA process were used as criteria of stability of the model. In addition, for the process to approximate the theoretical model of covariance-stationary (see Hamilton, 1994, chapter 3), we observe whether the variance of the residuals is constant over time, through the Breusch-Pagan-Godfrey heteroskedasticity tests.

Table 9 – *Estimated model for growth rate of output per worker*

Variable	Coefficient	Standard error	t	Prob.	I.C. 95%		I.C.99%	
					Bottom	Upper	Bottom	Upper
Δh	5.116300	0.548422	9.32	0.000	3.9929	6.2397	3.6000	6.6317
k_t	0.545852	0.145753	3.75	0.001	0.2472	0.8444	0.1430	0.9486
MA(1)	0.463500	0.209954	2.21	0.036	0.0334	0.8935	–0.1166	1.04365
SIGMASQ	0.000295	8.31E-0.5	3.55	0.001	124.5E-5	465.1E-5	23.4E-5	172.7E-5

Notes: $R^2 = 0.71, \bar{R}^2 = 0.68$; Durbin-Watson: 1.77; root of the inverted moving average equal to ±0.46i; F-statistic = 86,12 and Prob(F) = 0.00; I.C. is the confidence interval. Statistics based on a sample of 33 adjusted observations.

Table 10 – *Estimated model of the manufacturing share*

Variable	Coefficient	Standard error	t	Prob.	I.C. 95%		I.C.99%	
					Bottom	Upper	Bottom	Upper
h_{t-1}	0,86236	0.039289	21.90	0.000	0.782003	0.942713	0.75406	0.97062
θ_{t-1}	6.80E-05	2.95E-05	2.30	0.029	7.54E-06	0.000128	–1.35E-05	0.00012
$(G_{t-1} - 1)$	–0.08999	0.041443	2.17	0.038	–0.175235	–0.005225	–0.20523	0.02425

Notes: $R^2 = 0.89, \bar{R}^2 = 0.89$; Durbin-Watson: 2.07; F-statistic = 82.53; Prob(F) = 0.00; I.C. is the confidence interval. Statistics based on a sample of 32 adjusted observations.

Table 8 shows that the empirical model of the investment share in output is well adjusted. The coefficients of the exchange rate/wage ratio, $(\theta/w)_{t-1}$, sovereign risk, λ_{t-1}, and the moving average process, MA(1), have negative signs. The investment share with one lag, $(I/Y)_{t-1}$, the square of the exchange rate/wage ratio, $(\theta/w)_t^2$, the level of capacity utilization and the dummy variable 1999.Q4, (denoted by D94) have positive signs. The sovereign risk and the exchange rate/wage exhibit coefficients close to zero, even though they are not statistically insignificant main components, with moderate negative correlation (–0.56) and strong (–0.72) correlation.

Table 9 shows that the empirical model of labor productivity growth rate, y_t, is relatively well adjusted. The coefficients of the change in the manufacturing share in output, Δh, of the growth rate of capital per worker, k_t, and the moving average process, MA(1), with a lag, show positive signs. It is noteworthy that the correlation between Δh and y_t is 0.71, and that between k_t and y_t is 0.35.

Table 10 shows that the empirical model of the share of the manufacturing industry on total product is also relatively well adjusted. The coefficients of the share of the manufacturing industry on output, the real exchange rate and the technological gap minus one, all with a lag, h_{t-1}, θ_{t-1} and $(G_{t-1} - 1)$, have the expected signs. It should be noted that the real exchange rate, θ_{t-1}, has a very small estimated coefficient, even though its main component is not negligible, explaining 11.56% of the total variance of the manufacturing industry share in output, and even exhibiting a moderate positive correlation (0.53).

As for the stability of the functions, the inverse root of the polynomial of the MA process in the function for the investment share on output and in the function of the rate of growth of labor productivity, with values of 0.497 and ±0.46i, in module, are within the unit circle (root outside the circle). Therefore, the coefficients of the lagged variables are not exclusive, the MA process is invertible and the functions have desirable properties when lagged time series were used.[16]

7. Final remarks

This article investigates the causes of growth deceleration of the Brazilian economy since the beginning of the 1980s on the basis of a Keynesian-Structuralist theoretical framework, according to which the growth of labor productivity depends on structural changes or productive sophistications (transfer of labor and resources from activities with lower per-capita added value to activities with higher per-capita added value) and capital accumulation. In this context, we find that the pace of capital accumulation declined significantly since the late 1980s, and that this reduction was primarily caused by the reduction of the investment rate at current prices. A series of empirical procedures were presented for the estimation of the investment function, the technical progress function, and the structural change function for the Brazilian economy.

Estimates have shown that the rate of growth of labor productivity in Brazil depend on the dynamics of the share of the manufacturing industry in GDP, as well as the growth rate of the capital stock per worker. The evolution of the share of manufacturing industry in GDP, in turn, depend on the level of the real exchange rate and depend negatively on the technological gap. Finally, the estimation of the investment equation showed that the investment rate is a quadratic function of the exchange rate-wage ratio, a positive function of the degree of productive capacity utilization, and a negative function of the country risk premium.

Based on the results of the econometric tests, we can conjecture that the deceleration of the growth of the Brazilian economy since the 1980s was due to the combined effects of the reduction of the investment rate at current prices, and the reduction of the share of the manufacturing industry in GDP. The reduction in the investment rate is mainly due to the macroeconomic regime that prevailed since 1994 (then relaxed after 2006), which has restricted the expansion of aggregate demand, keeping the level of utilization of productive capacity at a low level (Oreiro and D'Agostini, 2017).

Another important factor was the external fragility of the Brazilian economy, which was expressed in two currency crises (1999 and 2002), and was responsible for maintaining the country risk premium at a high level, causing a negative impact on the investment rate. The appreciation of the real exchange rate observed since 1994 seems to have had a positive impact on the investment rate. Rather, the negative effect of the appreciation of the real exchange rate on growth was due to the dynamics of the share of the manufacturing industry in GDP. Since 1980, there was a significant reduction in the share of the manufacturing industry in GDP, which fell from 18.24% in 1980 to 12.3% in 2012. On the basis of the estimates made in this article, we know that (i) the reduction of the share of the manufacturing industry in GDP has a strong negative impact on the labor productivity growth rate; and (ii) the appreciation of the real exchange rate negatively affects, with a one-year lag, the share of manufacturing industry.

[16] Concerning the analysis of the residuals of the estimated functions, the Jarque-Bera test indicates the non-rejection of the normality hypothesis in all the estimated functions. Finally, we developed the Breusch-Pagan-Godfrey tests, the Glejser test and the Harvey test. The results show that in all the estimated functions the null hypothesis of non-heteroskedasticity is not rejected.

Thus, the appreciation of the exchange rate, which took place in Brazil mainly after 1994, had a negative net impact on the growth of the Brazilian economy.

Appendix – Further results

Table A1 reports the results of Granger causality tests between the growth rate of GDP, denoted by GRRATEGDP, and the growth rate of the capital stock, G, employing annual observations from 1980 to 2012. For series with one lag, we cannot reject the null hypothesis that the GDP growth rate does not Granger-cause the capital stock growth rate, but we can reject the null hypothesis that the capital stock growth rate does not Granger-cause the rate of GDP growth. For 2, 3 and 4 time lags, we can reject both the null hypothesis that the growth rate of GDP does not Granger-cause the growth rate of the capital stock, and that the growth rate of the capital stock does not Granger-cause GDP growth rate. For 5 lags, we cannot reject the null hypothesis that the growth rate of the capital stock does not cause the GDP growth rate, but we can reject the null hypothesis that the GDP growth rate does not Granger cause the rate of growth of the capital stock.

Table A1 – *Granger causality tests: relationship between capital accumulation and GDP growth (1980-2012)*

Lag	Null hypothesis	Sample	F	Prob.
1	GRRATEGDP does not Granger-cause; G does not Granger-cause GRRATEGDP	32	0.01394 6.59523	0.9068 0.0156
2	GRRATEGDP does not Granger-cause G; G does not Granger-cause GRRATEGDP	31	0.79042 1.25924	0.4643 0.3006
3	GRRATEGDP does not Granger Cause G; G does not Granger-cause GRRATEGDP	30	1.22627 0.87483	0.3228 0.4685
4	GRRATEGDP does not Granger Cause G; G does not Granger-cause GRRATEGDP	29	1.83708 0.32662	0.1613 0.8568
5	GRRATEGDP does not Granger Cause G; G does not Granger-cause GRRATEGDP	28	3.70987 0.83637	0.0188 0.5419

Table A2 – *Principal components of the investment rate on the product*

Importance	Variable	Eigenvalues	Difference	Individual proportion	Accumulated value	Accumulated proportion
1	(Y/I)	16.37	6.22	28.23%	16.37	28.23%
2	$(Y/I)_{-1}$	10.16	3.97	17.51%	26.53	45.74%
3	u	6.19	0.84	10.67%	32.72	56.41%
4	u_{-1}	5.35	1.29	9.23%	38.07	65.64%
5	Λ	4.06	0.90	7.00%	42.13	72.64%
6	λ_{-1}	3.16	0.43	5.45%	45.29	78.09%
7	θ/w	2.73	0.59	4.71%	48.02	82.80%
8	$(\theta/w)^2$	2.14	0.34	3.69%	50.16	86.49%
9	r	1.80	0.72	3.10%	51.96	89.58%
10	r_{-1}	1.08	0.10	1.85%	53.03	91.44%
11	Θ	0.98	0.18	1.68%	54.01	93.12%
12	$(\theta)^2$	0.79	0.06	1.36%	54.80	94.48%
13	θ_{-1}	0.73	0.21	1.27%	55.54	95.75%
14	$(\theta)^2{}_{-1}$	0.52	0.14	0.90%	56.06	96.65%
15	i_f	0.38	0.02	0.65%	56.44	97.30%
16	π_m	0.36	0.10	0.61%	56.79	97.92%
17	π_f	0.25	0.04	0.44%	57.05	98.36%
18	i_m	0.21	0.05	0.36%	57.26	98.72%
19	$i_{f_{-1}}$	0.16	0.03	0.27%	57.41	98.99%
20	i_{m-1}	0.13	0.02	0.22%	57.54	99.21%
21	θ/w	0.11	0.03	0.18%	57.65	99.39%
22	$(\theta/w)_{f_{-1}}$	0.08	0.01	0.14%	57.73	99.53%
23	$\pi_{f_{-1}}$	0.07	0.02	0.13%	57.80	99.66%
24	π_{m-1}	0.05	0.02	0.09%	57.86	99.75%
25	$(\theta/w)_{m-1}$	0.04	0.01	0.06%	57.89	99.82%
26	$\Delta\theta$	0.03	0.00	0.05%	57.92	99.86%
27	$\Delta(\theta)^2$	0.03	0.01	0.04%	57.95	99.91%
28	Δi_f	0.01	0.00	0.02%	57.96	99.93%
29	Δi_m	0.01	0.00	0.02%	57.97	99.95%
30	$\%u$	0.01	0.00	0.02%	57.98	99.97%
31	$\%(\theta)^2$	0.00	0.00	0.01%	57.99	99.98%
32	$\%\theta$	0.00	0.00	0.01%	57.99	99.98%
33	$\%i_m$	0.00	0.00	0.01%	57.99	99.99%
34	$\%i_f$	0.00	0.00	0.00%	58.00	99.99%
35	$\%r$	0.00	0.00	0.00%	58.00	99.99%
36	$\%(\theta/w)_m$	0.00	0.00	0.00%	58.00	100.00%
37	$\%(Y/I)$	0.00	0.00	0.00%	58.00	100.00%
38	$\%\pi_m$	0.00	0.00	0.00%	58.00	100.00%
39	$\%\pi_f$	0.00	0.00	0.00%	58.00	100.00%
40	$\%(\theta/w)_f$	0.00	0.00	0.00%	58.00	100.00%
41	$\%\lambda$	0.00	0.00	0.00%	58.00	100.00%
42	$\%r$	0.00	0.00	0.00%	58.00	100.00%
43	$\%r(Y/I)$	0.00	0.00	0.00%	58.00	100.00%
44	$\Delta\pi_m$	0.00	0.00	0.00%	58.00	100.00%
45	$\Delta\pi_f$	0.00	0.00	0.00%	58.00	100.00%
46	$\Delta(\theta/w)_f$	0.00	0.00	0.00%	58.00	100.00%
47	$\Delta\,\lambda$	0.00	0.00	0.00%	58.00	100.00%
48	$\Delta(\theta/w)_m$	0.00	0.00	0.00%	58.00	100.00%
49	Δr	0.00	0.00	0.00%	58.00	100.00%
50	Δr_m	0.00	0.00	0.00%	58.00	100.00%
51	Δu	0.00	0.00	0.00%	58.00	100.00%
52	r_{-2}	0.00	0.00	0.01%	58.00	100.00%
53	r_m	0.00	0.00	0.02%	58.00	100.00%
54	θ_{-2}	0.00	0.00	0.03%	58.00	100.00%
55	$(\theta)^2{}_{-2}$	0.00	0.00	0.04%	58.00	100.00%
56	u_{-2}	0.00	0.00	0.05%	58.00	100.00%
57	r_{m-2}	0.00	0.00	0.06%	58.00	100.00%
58	r_{m-1}	0.00	–	0.07%	58.00	100.00%

Principal components (rows 1–10) Do not discard or disposable frontier (rows 11–12) Disposable (rows 13–58)

Table A3 – *Principal components of the share of manufacturing industry in output*

Importance	Variable	Eigenvalues	Difference	Individual Proportion	Accumulated value	Accumulated proportion
1	h	3.4	1.3	37.78%	3.4	37.78%
2	h_{t-1}	2.1	0.93	23.33%	5.5	61.11%
3	$(G_{t-1} - 1)$	1.17	0.13	13.00%	6.67	74.11%
4	θ_{t-1}	1.04	0.64	11.56%	7.71	85.67%
5	θ^i	0.4	0.1	4.44%	8.11	90.11%
6	$(\theta - \theta^i)$	0.3	0	3.33%	8.41	93.44%
7	θ	0.3	0.1	3.33%	8.71	96.78%
8	${\theta^i}_{t-1}$	0.2	0.11	2.22%	8.91	99.00%
9	h_{t-2}	0.09	–	1.00%	9	100.00%

Principal components Do not discard or disposable frontier Disposable

Table A4 –*Principal components of the growth rate of labor productivity*

Importance	Variable	Eigenvalues	Difference	Individual proportion	Accumulated value	Accumulated proportion
1	Δh	2.77	1.32	39.63%	2.77	39.63%
2	k	1.46	0.42	20.82%	4.23	60.45%
3	k_{t-1}	1.03	0.31	14.82%	5.27	75.27%
4	k_{t-2}	0.73	0.06	10.36%	5.99	85.63%
5	y_{t-1}	0.66	0.32	9.47%	6.66	95.10%
6	h	0.34	0.34	4.90%	6.99	100%
7	h_{t-1}	-4.17E-16	---	0.00	7.00	100%

Principal components Do not discard or disposable frontier Disposable

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