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WHY HAS BRAZIL DEINDUSTRIALIZED SO MUCH?

AN EMPIRICAL INVESTIGATION

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Abstract: Brazil's share of manufacturing in GDP at constant prices fell from 14.5% in 1995.1 to 9.1% in 2022.1, a decline of 5.4 pp or 37%. We consider three hypotheses for such a sharp deindustrialization. The first is that Brazil's deindustrialization is a case of Dutch disease; the second is that the country deindustrialized prematurely; the third is that Brazil's industry is a peculiar case of Baumol's low productivity growth disease. The econometric analysis reveals the importance of Dutch disease and premature deindustrialization hypotheses but points to declining relative productivity as the main factor behind Brazil's deindustrialization.

Key words: Baumol's disease, Brazil, Dutch disease, OECD, premature deindustrialization

JEL codes: O14, O54, Q02

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1. *Introduction*[5]

This paper examines alternative hypotheses about Brazil's sharp deindustrialization experience from 1995 to 2022. In constant 2015.1 prices, Brazil's share of manufacturing in GDP fell from 14.5% in the first quarter of 1995 to 9.1% in the first quarter of 2022, a reduction of 5.4 pp, or 37%.

We consider three hypotheses. The first is that Brazil's deindustrialization is a case of Dutch disease resulting from a sustained increase in revenues from natural resource sectors. The hypothesized mechanism is that the Brazilian currency appreciates against foreign currencies as natural resource revenues increase. This makes the country's manufactured exports more expensive for other countries to buy, while imports become cheaper, making domestic manufacturing less competitive overall.

The classic economic model describing Dutch disease is that of Corden and Neary (1982), who also noted that cross-national capital inflows seeking to invest in the resource boom could strengthen the real exchange appreciation it generates. Independent periods of large foreign capital inflows, i.e. financial bonanzas, can also explain deindustrialization episodes, as Botta, Yajime, and Porcile (2023) point out.

Bacha (2013) estimates that the external bonanza generated by terms of trade increases and foreign capital inflows reached over 9% of Brazil's GDP between 2005 and 2011. He parametrizes a simple macroeconomic model in the spirit of Corden and Neary and concludes that this external bonanza could fully explain Brazil's deindustrialization during this period. Bresser-Pereira

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(2010) collects five other papers that analyze Brazil's deindustrialization from the perspective of the Dutch disease.

The second hypothesis is premature deindustrialization: a shift of economic activity towards non-manufactures, mainly services, alongside a similar trend in more advanced economies—as the GDP share of manufacturing typically follows an inverted U-shape path during development. The term premature, perhaps first used by Dasgupta and Singh (2007) and Palma (2005), was introduced in the development economics literature by Rodrik (2016). It is premature because, in the past, countries with per capita incomes at Brazil's level were still industrializing instead of experiencing deindustrialization.

Rodrik claims that premature deindustrialization is caused by trade and globalization. According to him, when developing countries opened up to trade, they were subjected to a double shock. Those without a strong comparative advantage in manufacturing became net importers of such products, reversing a process of import substitution. In addition, developing countries imported deindustrialization from advanced countries as they were exposed to the decline in the relative manufacturing prices in those countries, which squeezed manufacturing everywhere.

The emergence of China as a manufacturing powerhouse also helps explain deindustrialization outside Asia. Population aging, according to Cravino, Levchenko, and Rojas (2022), accounted for a fifth of the increase in the service share of consumption between 1982 and 2016 in the U.S. Other factors causing deindustrialization in advanced and developing countries were a trend toward outsourcing activities previously carried out within factories and the rise of high-tech service sectors such as banking and information technology. Morrone, Giovanini, and Berri (2022) claim that part of the manufacturing decline observed in Brazil from 2000 to 2015 is related to activities within the sector that migrated to services.

Palma (2005) extends the concept of Dutch disease. He uses it as a case of premature deindustrialization that includes not only natural resource booms, but also the development of export-service activities, mainly tourism and finance, and changes in economic policy (from import substitution industrialization to trade and financial liberalization). In this paper, we stick to the traditional concept of the Dutch disease because its determinants differ from those that cause premature deindustrialization, as characterized by Rodrik.

The third hypothesis is that the Brazilian industry is a peculiar case of the so-called Baumol's disease. Baumol (1967) asserts that high-productivity growth sectors (such as manufacturing in the US) tend to shrink and lagging sectors (such as services in the US) tend to grow as a share of GDP in current prices. Baumol was not bound by what happens to GDP shares in constant prices. Using industry data for 1948-2001, Nordhaus (2008) examines Baumol's disease for the US economy. He finds that technologically stagnant sectors (mainly services) had declining relative real output. As shown in the next section, this is also the case for Brazil, except that the technologically stagnant sector is manufacturing. Veloso et al. (2024) document that manufacturing had the lowest labor productivity growth from 1995 to 2023 among the twelve sectors of activity considered in the Brazilian national accounts. This peculiarity (the causes of which have yet to be explained) would tend to reduce the share of manufacturing in GDP at constant prices.

Brazil's deindustrialization--understood as a continuous decline in the GDP share of manufacturing in constant prices--probably dates from the late 1970s (cf. Bonelli, Pessoa, and Matos, 2013), much earlier than the initial year of our analysis, 1995. We started in 1995 because we needed quarterly data to generate enough observations for our time series analysis and a consistent set of quarterly national accounts dates from this year. In addition, Brazil's official statistics body (IBGE) significantly revised the national accounts in 1995, and figures from previous years are not comparable with those from that date onward.

There are many empirical studies of Brazil's deindustrialization. But to our knowledge only two papers use econometric models like ours to derive their results. Marconi and Barbi (2011) estimate panel regressions for the period 1995-2007 with the GDP shares of 28 manufacturing sectors in current prices as the dependent variable and the lagged values of the dependent variables, GDP per capita and its square, effective real sectoral exchange rates, GDP shares of gross investment rates, shares of imported inputs in sectoral intermediate consumption, among others, as independent variables. Their results confirm that manufacturing GDP shares are strongly autoregressive and follow an inverted U-shaped path with economic growth but are otherwise inconclusive.

Iasco-Pereira and Morceiro (2024) estimate time series regressions with annual data for the period 1947-2021, with the manufacturing share of GDP in current prices as the dependent variable and the real effective exchange rate and infrastructure investment, among others, as independent variables. They find a significant relationship between the manufacturing share in current prices and the real exchange rate, but this may simply be because relative prices in manufacturing are strongly associated with the real exchange rate. When the real exchange rate appreciates, the relative prices of manufacturing fall, which reduces the current price share of manufacturing in GDP. For this reason, a valid test of Dutch disease must use the constant price share of manufacturing as the dependent variable. Furthermore, an appropriate instrumental variable must replace the real exchange rate since it is an endogenous variable. Finally, as shown in Morceiro (2021), using pre-1995 data requires several heroic corrections to make them minimally compatible with the post-1995 national accounts, raising the prospect of measurement errors.

In the next section, we discuss the quarterly evolution of the Brazilian manufacturing share of GDP since 1995 and its possible determinants according to the three hypotheses. We show the evolution of the manufacturing share in current and constant prices. However, in the econometric analysis, we limit our attention to real values, since nominal values conflate movements in quantities and prices, which are best kept separate when trying to understand patterns of structural changes and their determinants. We do not provide an econometric analysis of the evolution of Brazil's manufacturing employment share, as a consistent series for this variable is only available quarterly from 2012 onwards.

Section three provides econometric tests of the hypotheses about the causes of Brazil's deindustrialization. Section four concludes. Appendix A describes time series econometric tests. Appendix B presents additional regressions. The Data Supplement contains all the data we used, including their sources.

2. *Deindustrialization and its interpretation*

We extract quarterly data on Brazil's industrialization rates from the national accounts: the share of manufacturing in GDP at constant 2015.1 prices from 1995.1 to 2022.4 and at current prices from 1996.1 to 2022.4. These are shown in Figure 1 as the blue and orange lines, respectively.[6]

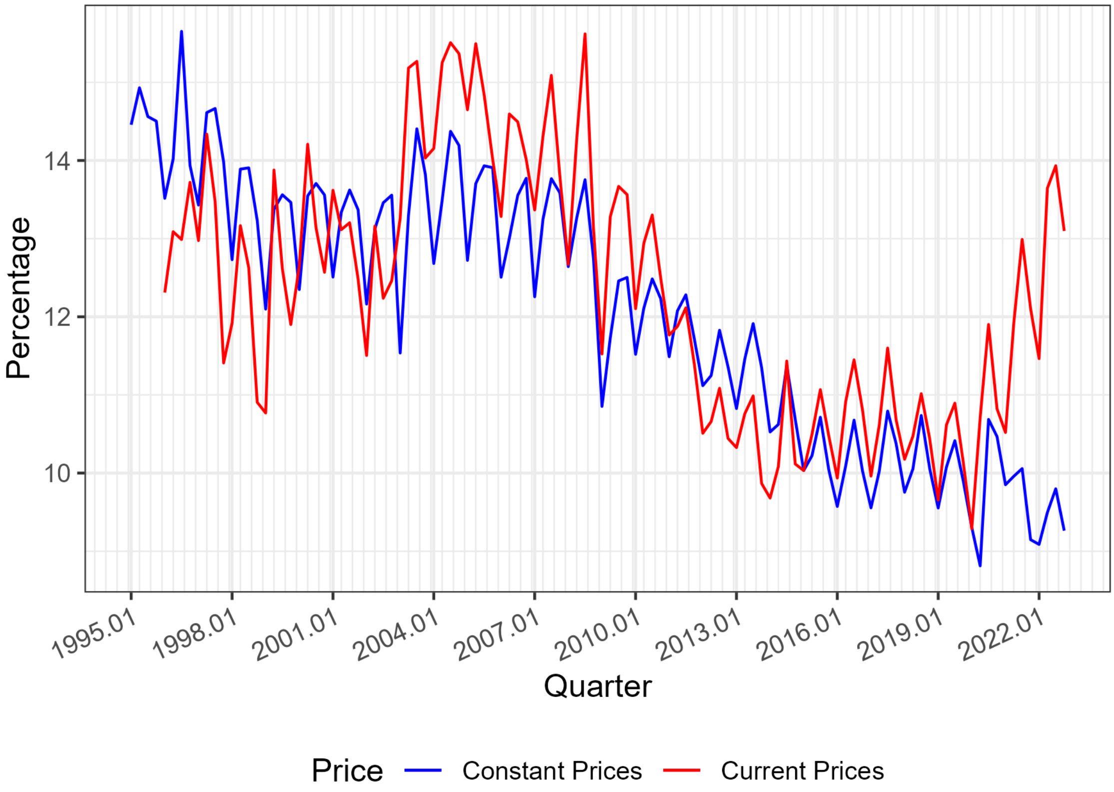
Both series have a pronounced seasonal pattern within the year, with a peak in the third quarter and a trough in the first quarter-more on this in section three. In the following, we make intertemporal comparisons always starting from the first quarter.

[6] GDP is in market prices; manufacturing value added is in basic prices.

Brazil's industrialization rate in current prices starts at 12.3% in 1996.1 and reaches a low of 9.3% in 2020.1, for a total deindustrialization of 3 pp, or 24%. There is some re-industrialization in current prices in the early years of the period, as the share of manufacturing in GDP rises from 12.3% in 1996.1 to 14.6% in 2005.1. The industrialization rate in current prices changes little from 2005.1 to 2008.1, when it begins a sharp decline to 9.7% in 2014.1, a value around which the series stabilizes until 2020.1. Thereafter, the current price series rises sharply and ends at values like those at the beginning of the series. The reindustrialization surges from 1996 to 2005 and from 2020 to 2022 are probably related to the significant depreciation of the Brazilian currency during these periods: manufacturing products are tradable goods, while most of GDP is non-tradable services. Currency depreciation raises the prices of tradables relative to non-tradables, thereby increasing the share of manufacturing in GDP at current prices.

Thus, in current prices, Brazil's deindustrialization appears to have occurred in the six-year period from 2008 to 2014.

Fig. 1: Brazil's Industrialization Rates in Current and Constant Prices, 1995.1-2022.4



Source: IBGE quarterly national accounts, processed by authors.

This is not the case for the share of manufacturing in GDP at constant prices, which is important for our empirical analysis. As the blue line in Figure 1 shows, Brazil's deindustrialization in constant prices occurs for almost the entire period. In 2015.1 prices, the GDP share of manufacturing falls from 14.5 percent in 1995.1 to 9.1 percent in 2022.1, a decline of 5.4 percentage points, or 37 percent.

2.1. The Dutch disease

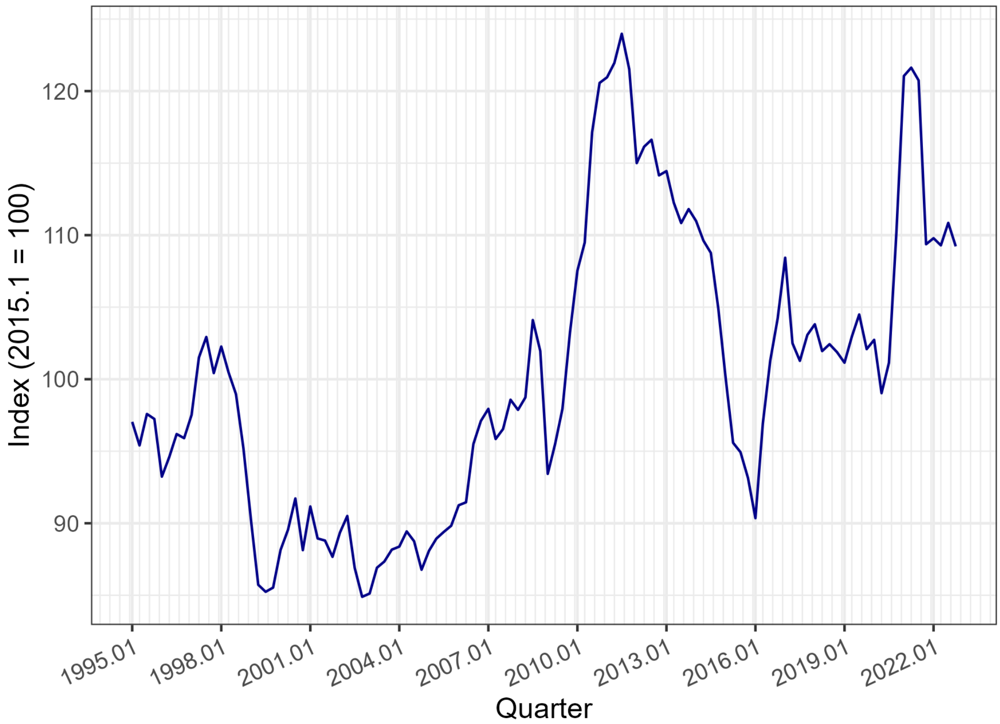
According to the Dutch disease hypothesis, Brazil's deindustrialization would result from increased revenues from natural resources. Different indices could describe the strength of natural resource revenues. Still, the terms of trade (i.e., the ratio between the prices of export and import goods) are often used in

Brazil because its exports are largely primary products, while its imports are mainly manufactured goods. We capture the financial component of the Dutch disease with the Dollar Index, which is discussed below.

Figure 2, using data from Funcex [Fundação Centro de Estudos do Comércio Exterior], shows the evolution of Brazil's terms of trade from 1995.1 to 2022.4, with 2015.1 = 100.[7] The graph illustrates the ups and downs of this variable, with a long upswing from 1999 to 2011 and an upward drift for the whole series. Visually at least, the terms of trade movements roughly coincide with the deindustrialization in constant prices during this period.

Fig. 2: Brazil's Terms of Trade, 1995.1 - 2022.4

(2015.1 = 100)



Source: Funcex, processed by the authors.

The Dutch disease hypothesis does not postulate a direct relationship between the terms of trade and deindustrialization, as there is an intervening

[7] We thank Henry Pourchet from Funcex for this data.

variable, namely the real exchange rate. Supposedly, an improvement in the terms of trade appreciates the real exchange rate, and this appreciation crowds out domestic manufacturing. However, other variables affecting the real exchange rate may influence its impact on industrialization rates.

We analyze the behavior of this variable using the real exchange rate of the Real against the U.S. dollar calculated by Brazil's Central Bank.[8] This is because the prices of exports and imports entering the terms of trade are in U.S. dollars; more importantly, many traded goods, especially commodities, are priced in U.S. dollars, while about 90% of Brazil's trade is denominated in this currency.

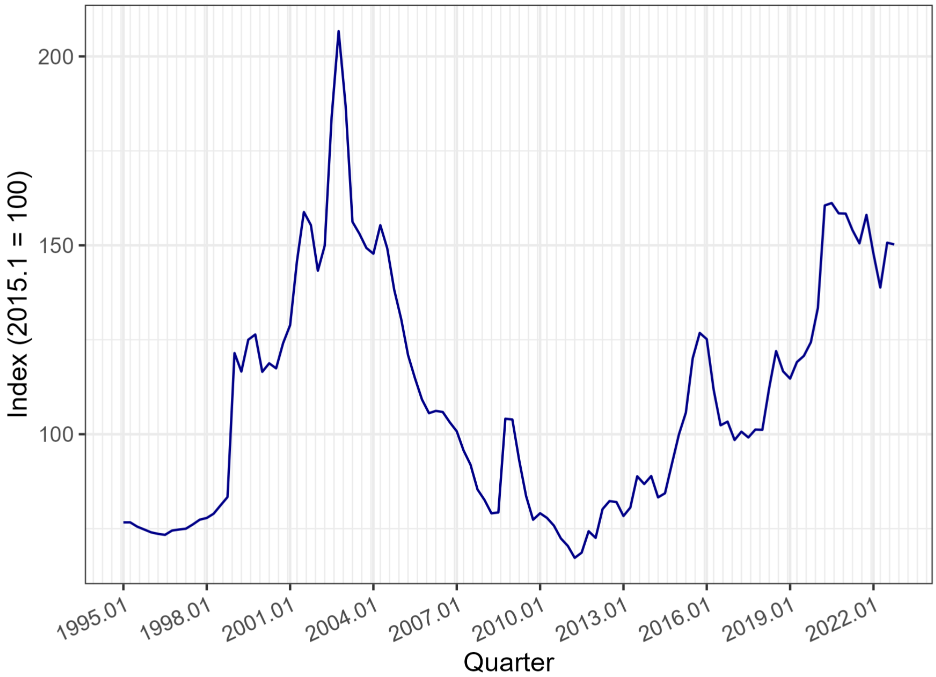
Previous econometric analyses of Brazil's deindustrialization have used the real effective exchange rate (REER) instead of the Real/USD real rate (see Iasco-Pereira and Morceiro (2024) and Marconi and Barbi (2011)). We also perform econometric exercises with the REER and report the results (which are very much like those with the Real/USD real rate) in Appendix B.

The volatile behavior of the Real/USD real exchange rate from 1995.1 to 2022.4 (with 2015.1 = 100) is shown in Figure 3 (higher values indicate a depreciation of the Real/USD rate). There is relative stability during the managed exchange rate period from 1995.1 to 1998.4. This is followed by a period of sharp depreciation, culminating in 2002.3 under the so-called Fear of Lula effect. Sebastian Edwards' (2002) article in the Financial Times of August 4, 2002 ("Brazil's only hope of avoiding collapse") illustrates the fear of financial market participants that the ascension of the leftist Luiz Inacio Lula da Silva to the presidency of Brazil would lead the country to default on its public debt.

[8] The price indexes to calculate the real rates are the IPCA for Brazil and the CPI-U for the U.S. We thank Fernando Rocha and Thiago Vieira, from Brazil's Central Bank, for this data.

From 2003.1 to 2011.2, Brazil's currency experienced a sharp real appreciation, in line with the China-induced commodity boom. This was followed by a depreciation trend until the end of the period. We conclude that the terms of trade have been an ingredient, but other factors undoubtedly influenced the real exchange rate in the period.

Fig. 3: Real/USD Real Exchange Rate, 1995.1-2022.4 (2015.1=100)



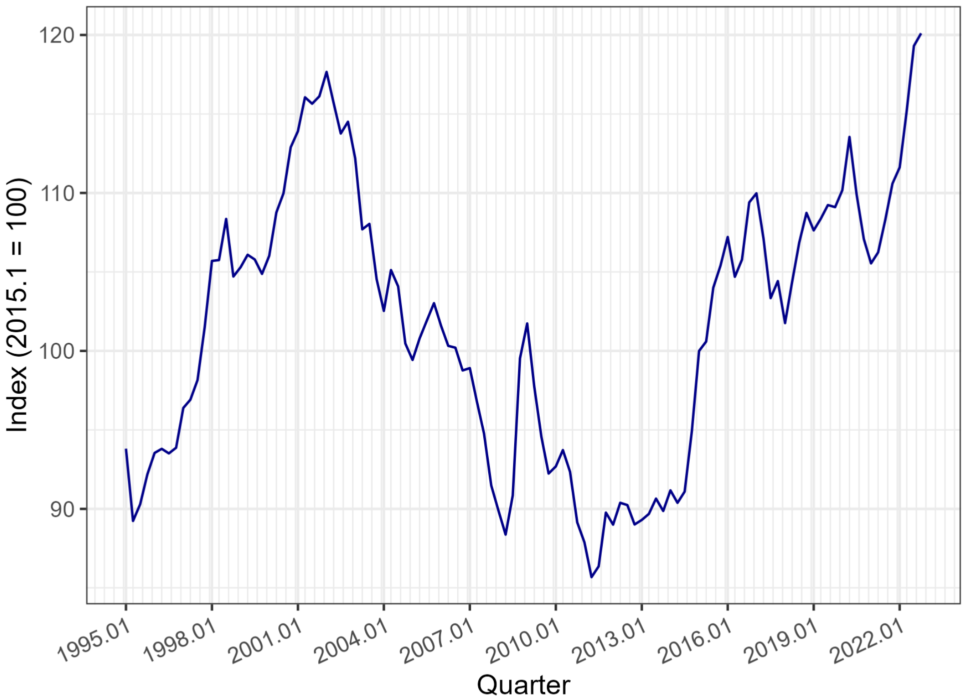
Source: Brazil's Central Bank

One candidate is the strength of the U.S. dollar in the global economy, as depicted in Figure 4--this is the U.S. Fed trade-weighted real broad dollar index, the real exchange rate of a basket of currencies against the U.S. dollar, with 2015.1 = 100 (higher levels indicate U.S. dollar appreciation).

Several recent studies show that movements in the Dollar Index are strongly associated with capital flows to emerging market economies (EMEs) (see Goswami, Pontines, and Mohammed, 2023, for references). Depreciation of the Dollar Index is associated with financial prosperity in EMEs, while appreciation is associated with financial distress in these markets. Thus, the dollar index captures the financial component of the Dutch disease pointed out by Botta, Yajime, and Porcile (2023).

The Dollar Index doesn't show a clear trend over this period. However, as expected from the above considerations, its cyclical behavior resembles that of the Real/USD rate: it appreciates from 1995 to 2001, depreciates until 2011, and appreciates again until 2022.

Fig. 4: Real Broad Dollar Index, 1995.1-2022.4
(2015.1=100)



Source: U.S. Fed. The authors merged the old with the new series.

In the econometric analysis of section three, we'll use the terms of trade and the Real/USD real exchange rate as alternative explanatory variables to capture the effect of the Dutch disease on deindustrialization.

2.2. *Premature deindustrialization*

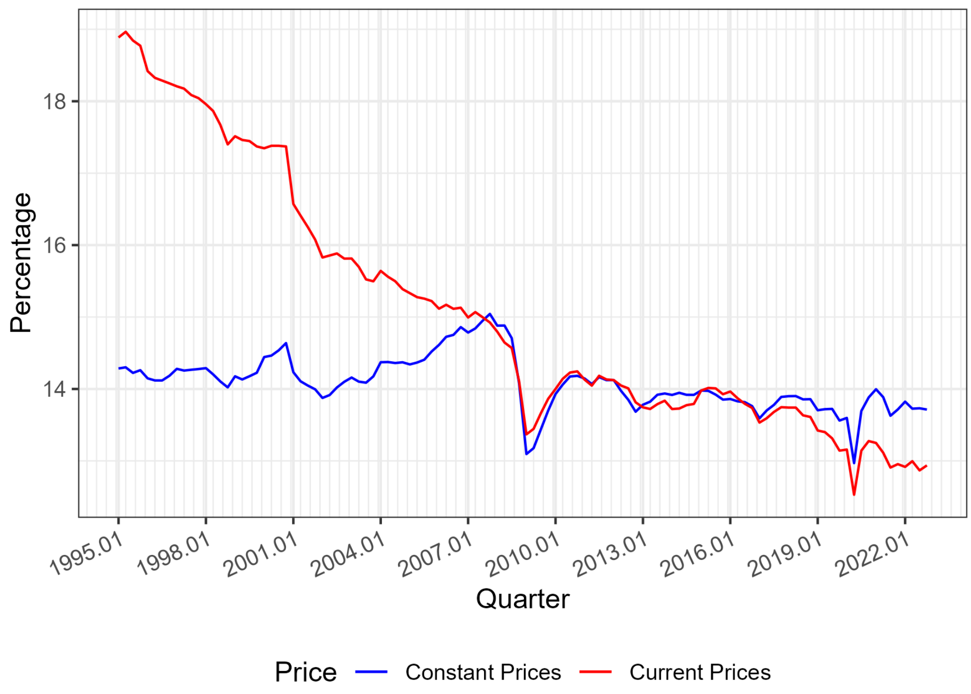
To address the hypothesis of premature deindustrialization, we look at the evolution of industrialization rates in the OECD (Organization for Economic

Cooperation and Development), that is, the share of manufacturing in GDP in the OECD at current and constant prices, as reported by UNIDO (United Nations Industrial Development Organization). This group of mainly high-income countries is not affected by Dutch disease (except to a small extent due to the presence of Australia, Chile, New Zealand, and Norway). The behavior of their manufacturing sector is undoubtedly representative of the rise of the service economy and the emergence of China as a manufacturing powerhouse, factors that, in principle, negatively affect the rate of industrialization in advanced countries.

We ask whether deindustrialization in the OECD is a reasonable explanation for deindustrialization in Brazil. If so, a broader international phenomenon other than the Dutch disease would be behind Brazil's deindustrialization. Since Brazil has a per capita income of about 1/3 that of the OECD, this correspondence would indicate a case of premature deindustrialization.

Figure 5 shows the OECD industrialization rates in current (orange line) and constant 2015.1 prices (blue line) for 1995.1-2022.4. The UNIDO databases only provide annual data on OECD industrialization rates. We decomposed these figures into quarters using quarterly and annual data for a subset of 20 OECD countries. We used the relationships between quarterly and annual data on industrialization rates in these countries, year by year, to generate the quarterly figures for the OECD. See the Data Supplement for more information.

Fig. 5: OECD's Industrialization Rates, 1995.1 - 2022.4



Sources: UNIDO and OECD, processed by authors.

The OECD's share of manufacturing in GDP declines from 1995 to 2022, but the series in current and constant prices behave very differently. The orange line in Figure 5 shows that the GDP share of manufacturing in current prices falls continuously and very sharply: it starts at 18.9% in 1995.1 and ends at 12.9% in 2022.1. This decline is larger than that of Brazil in current prices.

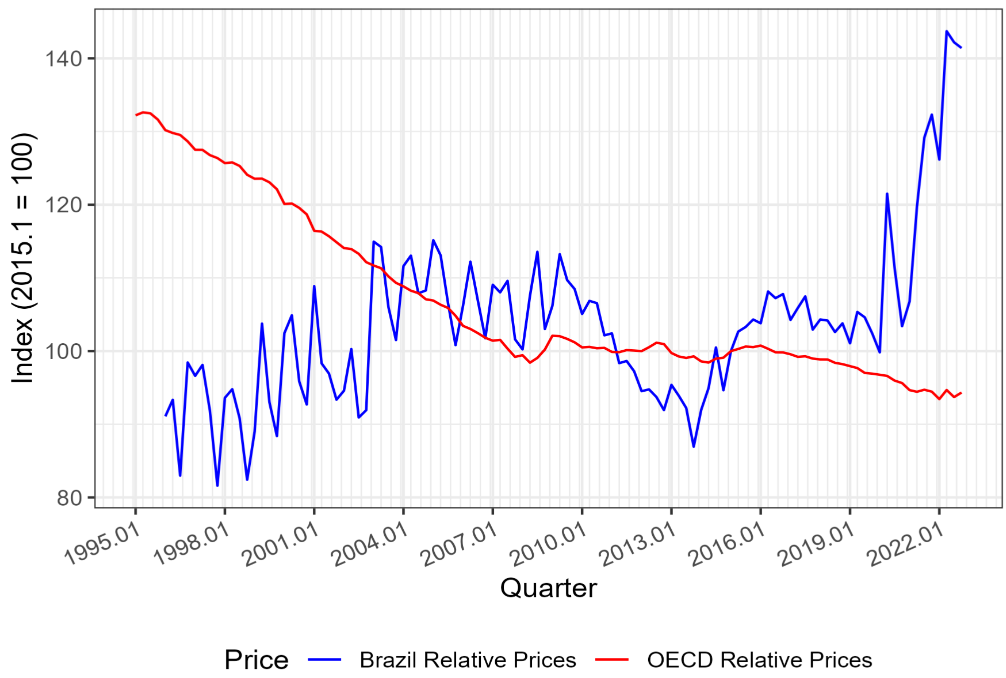
The blue line in Figure 5 shows that the decline in OECD manufacturing's share of GDP in constant prices is tiny: from 14.3% in 1995.1 to 13.8% in 2022.1. The blue line is relatively flat, around 14%, until 2005.3. It rises to 15% in the following two years, falls to 13% with the international financial crisis in 2008, and then returns to its initial level of nearly 14%.

Given the behavior of the series at constant prices, there seems to be little "mature" deindustrialization in the OECD that could explain Brazil's "premature" deindustrialization from 1995 to 2022. We return to this question in the next section.

Rodrik (2016), using data from the late 1940s/early 1950s to the early 2010s, did not find a decline in constant-price manufacturing shares in advanced countries and attributed the fall in the current-price share to the higher rate of technical progress in manufacturing relative to other economic activities—a supply surge that, faced with inelastic demand, caused relative prices to fall. With the addition of a China effect that further reduced the prices of manufactured products, this hypothesis seems to explain the behavior of the series in Figure 5.

The orange line in Figure 6 shows that the relative price of manufacturing in the OECD (implicitly obtained by dividing the share of manufacturing in GDP at current prices by that at constant prices) tended to fall from 1995.1 to 2022.4. In Brazil, on the other hand, the relative price of manufacturing tended to rise, with significant fluctuations, over the period, as shown by the blue line.

Fig. 6: Relative prices of manufacturing, 1995.1 - 2022.4 (2015.1=100)



Source: Estimated from the GDP manufacturing shares in current and constant prices.

2.3. Baumol's disease Brazilian style

This brings us to Baumol's disease. The original version of this disease assumes that manufacturing is a sector with fast relative productivity growth and falling relative prices. Services would be the lagging sectors, whose relative prices would rise with economic growth. The declining trend of manufacturing relative prices in the OECD is consistent with this thesis. This is not the case in Brazil, where manufacturing relative prices, if anything, tend to rise rather than fall.

What can be said about the evolution of relative labor productivity in manufacturing? By this, we mean real value added in manufacturing divided by the number of persons employed in manufacturing, as a ratio of real aggregate value added or real GDP divided by the number of persons employed in the economy.

For Brazil, we only have annual data on this variable.[9] We couldn't even get annual data for the OECD and had to settle for a relative productivity series for the G7 countries only. See the Data Supplement for the steps involved in constructing this series.

Figure 7 shows the evolution of the relative productivity of manufacturing in the G7 (blue line) and Brazil (green line) from 1995 to 2022/23, in 2015 prices[10]. For the G7, the line has a positive slope: labor productivity in manufacturing grows faster than in the whole economy. The opposite is true for Brazil: the relative labor productivity in manufacturing

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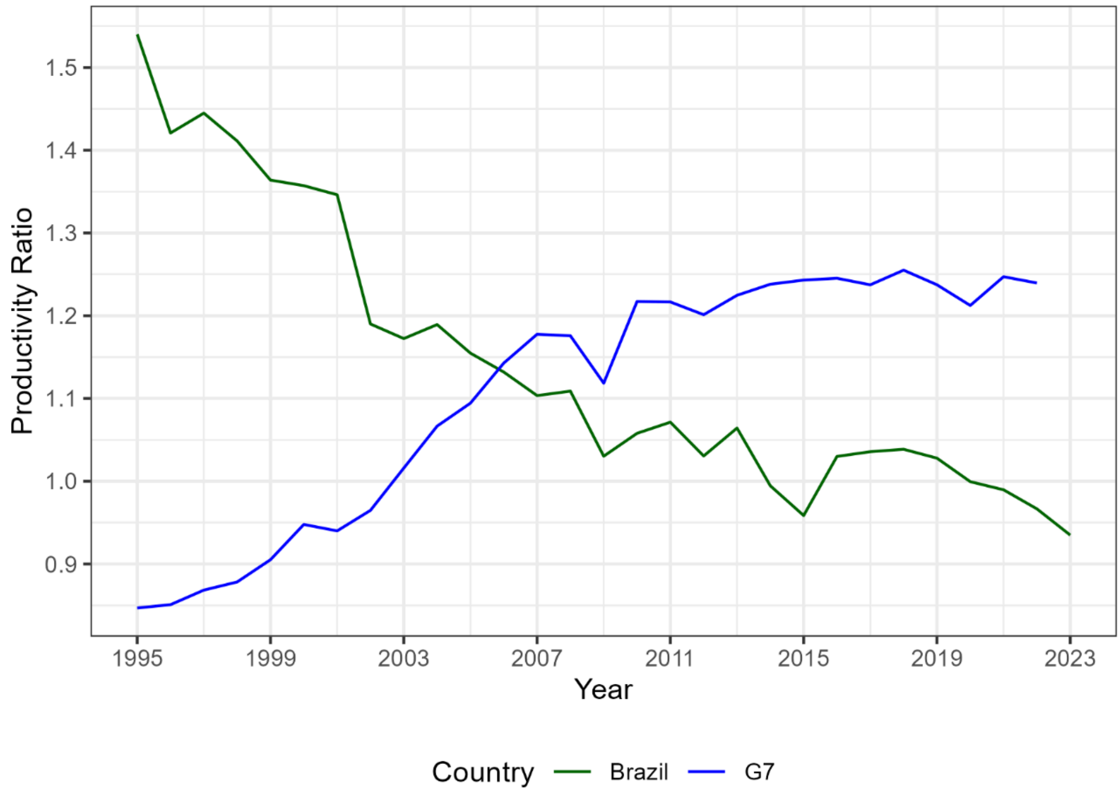
[9] We are indebted to Fernando Veloso for this data.

[10] For Brazil, relative manufacturing productivity is calculated with reference to aggregate value-added productivity (GDP excluding indirect taxes minus subsidies). For the G7, the reference is GDP's productivity.

declines substantially. Manufacturing labor productivity was 54% higher than in the whole economy at the beginning of the period; in 2023, it was 7% lower. For the G7, labor productivity in manufacturing was 15% lower than the whole economy in 1995; in 2022, it was 24% higher.

Fig. 7: Relative labor-productivity in manufacturing:
Brazil and the G7, 1995-2022/23

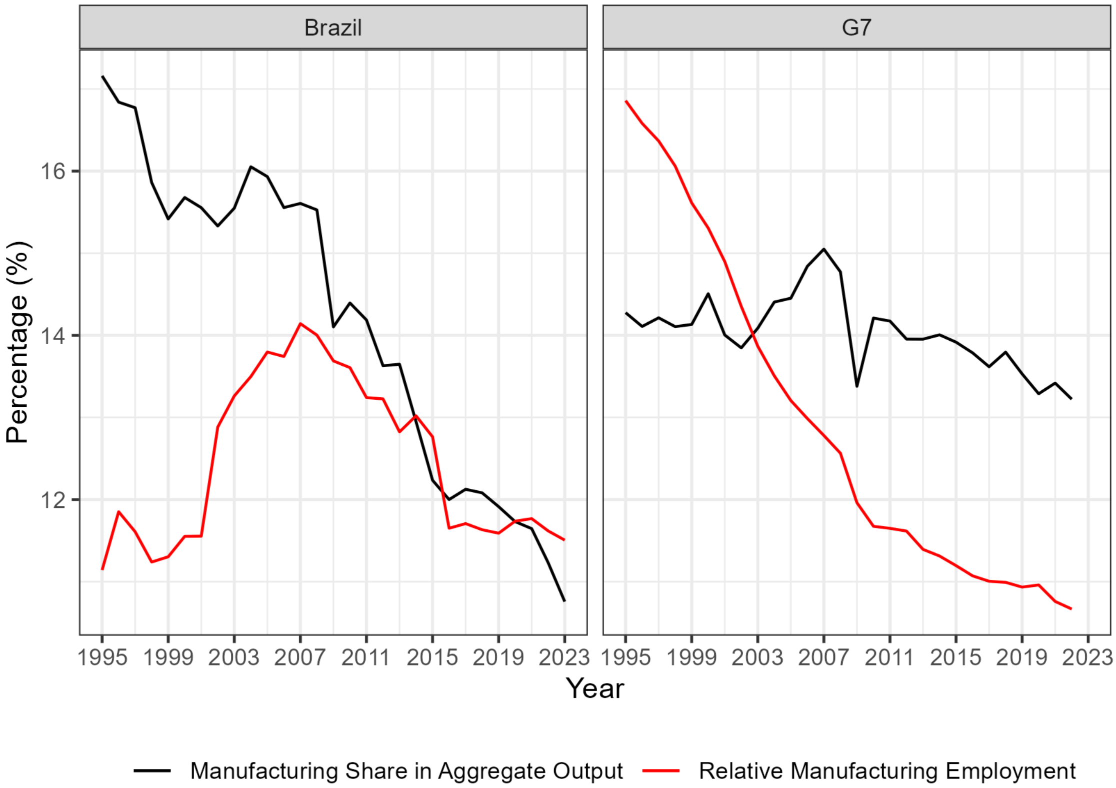


Sources: EUKLEMS, IBRE/FGV, IBGE, UN, and OECD, processed by authors

Figure 8 shows the evolutions of manufacturing shares in aggregate output and relative manufacturing employment for Brazil and the G7, 1995-2022/23, in 2015 prices[11].

[11] In the case of Brazil, aggregate output refers to aggregate real value added (GDP excluding indirect taxes minus subsidies). In the case of the G7, aggregate output refers to GDP.

Fig. 8: Manufacturing shares in aggregate output and relative manufacturing employment: Brazil and the G7, 1995-2022/23



Sources: EUKLEMS, IBRE/FGV, IBGE, UN, and OECD, processed by authors

Figure 8 shows that, in the G7, the share of manufacturing in total output declined slightly, but relative employment in manufacturing declined significantly. This result is consistent with the earlier findings of Rodrik (2016), among others, who showed that, in advanced countries, deindustrialization manifested itself as a decline in relative manufacturing employment, while the share of manufacturing in GDP at constant prices remained largely unchanged. In Brazil, on the other hand, the share of manufacturing employment rose and then fell to end the period at a level similar to that at the beginning. Meanwhile, the share of manufacturing in constant prices fell sharply, in line with the collapse in relative manufacturing productivity shown in Figure 7. In the advanced countries, deindustrialization occurred in terms of employment; in Brazil, it occurred in terms of output.

The divergent trends in relative manufacturing productivity lie behind this difference.

It is beyond the scope of this paper to investigate why manufacturing productivity behaved so poorly in Brazil. We list five hypotheses that deserve further research:

i. Considera (2017) suggests that the decline in labor productivity was generated by low investment rates in manufacturing, caused among other factors by the high cost of capital in Brazil. Bonelli and Pinheiro (2017) decompose the evolution of labor productivity in 20 manufacturing sectors from 2007 to 2013 and find that the capital-labor ratio declined in most sectors, explaining 30% of the decline in labor productivity. These results suggest that the low investment hypothesis deserves further investigation.

ii. A second hypothesis is that low-productivity sectors became more important in manufacturing, perhaps because high-productivity sectors faced increased competition from imports or weak domestic demand. Carvalho (2010) conducted an empirical study comparing Brazil's industrial structure with other countries and concluded that the country's industry began a process of specialization at a lower level of per capita income than other countries. This process was characterized by an increase in the weight of less technologically sophisticated sectors, which already accounted for a high share of industrial output. In an empirical analysis of the period 1970-2016, Morceiro and Guilhoto (2023) identified what they call "normal" deindustrialization in low-productivity sectors and "premature" deindustrialization in high-productivity sectors. Monteiro and Borghi (2023) find that the GDP share of high-tech manufacturing sectors declined the most within manufacturing over the 2000-2018 period. These are important findings, but they are not consistent with Bonelli and Pinheiro (2017), who decompose the labor productivity decline in manufacturing from 2007 to 2013 and find that compositional changes (i.e., differing shares of value added and employment of 20 manufacturing sectors) had little impact on the evolution of overall labor productivity in manufacturing.

iii. Carneiro (2002), among others, claims that import penetration would have disrupted domestic manufacturing value chains, with adverse effects on output and productivity. This assumption is not consistent with the available empirical evidence. In an econometric analysis of 28 manufacturing sectors over the period 1995-2007, Marconi and Barbi (2011, p. 68) find a negligible impact of the share of imports in the consumption of intermediate goods on the GDP share of these sectors: the contemporaneous effect is positive, while the one-year lagged effect is negative. The algebraic sum of the two coefficients is close to zero. In an empirical analysis from 1995 to 2011, Rios and Araujo Jr. (2013) conclude that it is impossible to explain the negative performance of any Brazilian manufacturing sector by the evolution of the degree of import penetration. Econometric analyses of the impact of the reduction of tariff and non-tariff barriers to imports in the 1990s agree that it had a positive effect on the total factor productivity of industrial firms: Hay (2001) and Muendler (2004) emphasize the positive effect of competitive pressure from imports on the adoption of new technologies by local firms; Ferreira and Rossi (2003), Schor (2004), and Lisboa et al. (2010) find that the use of more efficient imported inputs also increased productivity.

iv. Branstetter and Laverde-Cubillos (2024) document evidence that the currency appreciation associated with the commodity boom of the 2000s led to a significant and persistent decline in R&D spending and investment in technological upgrading by Colombian firms. Even after commodity prices dropped in the mid-2010s, inducing a long-lasting Colombian currency devaluation, investments in R&D and technology upgrading remained at subdued levels, which these authors impute to hysteresis in firms' technological investments. Similarities between Colombia and other commodity exports suggest to Branstetter and Laverde-Cubillos that their findings may apply to other countries.

v. Figure 7 shows that Brazil's relative manufacturing productivity was 54% higher than the economy's average in 1995. In the following years, it declined steadily. By 2023, it was 7% lower than the economy's average. According to the IBRE Productivity Observatory, this movement was accompanied by a spectacular increase in agricultural productivity: it started at 17% of the economy's average in 1995 and reached 73% in 2023.[12] Taken as a group, the relative productivities of the other sectors of the economy besides manufacturing and agriculture remained almost invariable. The downward trend in relative productivity in manufacturing was the mirror image of the upward trend in agriculture. Thus, one could argue that what happened in Brazil was not a peculiar case of Baumol's disease in manufacturing but simply an extraordinary increase in agricultural productivity. However, this catch-up hypothesis does not explain why manufacturing productivity not only did not follow the example of agriculture but, on the contrary, declined in absolute terms. Bacha (2024), Menezes Filho and Kannebley Jr. (2013), and Rios and Veiga (2022) argue that insufficient exposure to technological advances and creative

[12] These values are in 2015 prices, according to the tables in the Data Supplement, which Fernando Veloso graciously prepared for us. Veloso et al. (2024) present the data in 2021 prices.

destruction forces of international trade would be part of the explanation.

3. Regression results

We proceed in two steps. First, we estimate a regression of the Real/USD real exchange rate (RER) on Brazil's terms of trade and the broad real dollar index for 1995.1 to 2022.4. We include three dummy variables in this regression: one for 1995.1 to 1998.4, when the exchange rate was managed before the float in January 1999; another for 2002.3 to 2003.1, when the fear of Lula was manifest; and a third for 2020.2 to 2021.4 on account of the COVID crisis.

Next, we use a lagged fitted value of the RER, or else a lagged value of the terms of trade, as independent variables in regressions for the GDP share of manufacturing in Brazil at constant prices (which we also refer to as Brazil's industrialization rate), in the period 1996.1-2022.4. Preliminary tests indicated which lag of the RER or the terms of trade performed better. These two indices--lagged fitted RER or lagged terms of trade--capture the Dutch disease effect. Results using the real effective exchange rate instead of the Real/USD real rate are presented in Appendix B.

The coefficient on the share of OECD manufacturing in GDP at constant prices captures the premature deindustrialization effect.

Another regressor is a time trend. This is designed to capture the effect of the Brazilian version of Baumol's disease on the rate of industrialization. As discussed in the previous section, this disease has manifested itself in Brazil as a decline in relative labor productivity in manufacturing. Figure 7 shows that this variable declined almost continuously from 1995 to 2023. It has a correlation coefficient of -0.93 with the time variable. In the absence of a better alternative that future research could unveil, this high correlation suggests using a time trend to capture the effect of Baumol's disease on Brazil's rate of industrialization. The time trend also helps to reduce the autocorrelation in the residuals.

As explained earlier, we do not have quarterly data on labor productivity. But even if we did, we couldn't use them directly in the regression since the real value-added ratio equals the labor productivity ratio multiplied by the employment ratio. Instrumental variables for the productivity ratio would have to be used to avoid a spurious regression, and the time trend can be seen as a proxy for these instruments.

Four lagged values of the dependent variable are also included in the regressions. This has an economic justification: the industrialization rate is a slow-moving variable, and a statistical one: the lags help to alleviate biases generated by autocorrelation in the residuals.

Finally, there are the seasonal/quarterly dummies, which capture the ups and downs of the industrialization rate within the year.

In Appendix A, we present a series of statistical tests to evaluate the validity of our regressions. The autocorrelation and partial autocorrelation functions demonstrate the absence of individual residual autocorrelation in our regressions. Along with the results of the Ljung-Box tests, we conclude that there should not be any residual autocorrelation in the regressions, implying that the estimators are consistent. Since the real exchange rate regression does not include lags of the dependent variable as a regressor, residual autocorrelation should not affect the consistency of the estimators in this case.

Appendix A also presents the results of the Engle-Granger cointegration test for all regressions. The Engle-Granger test performs a unit-root test–we use the Augmented Dickey-Fuller (ADF) test–in the regression residuals. They indicate that none of the regressions exhibit integrated residuals, even though all dependent variables are integrated. This provides evidence that the variables are cointegrated and the regressions are not spurious but indicate genuine relationships.

The results of the regressions are summarized in Table 1. The coefficients are all linear, and in the case of the industrialization rate, they indicate short-term effects. We'll comment on the elasticities derived from the linear coefficients for the RER regression. These are calculated at the mean values of the relevant variables. For the industrialization rate regressions, we'll comment on short- and long-run effects. The former are expressed directly by the linear coefficients, the latter by these coefficients multiplied by 1/(1-z), where z is the sum of the coefficients of the four lagged values of the dependent variable. For example, the value of z in the regression in column (2) of Table 1 is 0.663 (= 0.262+0.146−0.037+0.292), which yields 1/(1-z) = 2.97.

Table 2 summarizes the dependent variables' responses to changes in the independent variables calculated from regressions (1) and (2) in Table 1.

Table 1: Regression Results

	RER	BR Ind. Rate - Con.	BR Ind. Rate - Con.
	(1)	(2)	(3)
Constant	−7.522	−3.057+	−4.390**
	(0.761)	(0.070)	(0.006)
Terms of Trade	−0.736***		
	(<0.001)		
Real Broad Dollar Index	1.878***		
	(<0.001)		
Dummy Managed	−26.756***		
	(<0.001)		
Dummy Lula	49.956***		
	(<0.001)		
Dummy Covid	42.983***		
	(<0.001)		
1st Lag BR Ind.Rate		0.262**	0.257*
		(0.007)	(0.022)
2nd Lag BR Ind.Rate		0.146	0.147
		(0.134)	(0.206)
3rd Lag BR Ind.Rate		−0.037	−0.038
		(0.701)	(0.744)
4th Lag BR Ind.Rate		0.292**	0.289***
		(0.001)	(<0.001)
3rd Lag Terms of Trade		−0.009*	
		(0.038)	
3rd Lag Fitted RER			0.003+
			(0.058)
OECD Ind.Rate		0.563***	0.588***
		(<0.001)	(<0.001)
Time Trend		−0.011**	−0.013***
		(0.005)	(<0.001)
2nd Quarter		0.829***	0.817***
		(<0.001)	(<0.001)
3rd Quarter		1.159***	1.153***
		(<0.001)	(<0.001)
4th Quarter		0.567**	0.563**
		(0.002)	(0.002)
Num.Obs.	112	108	108
R2	0.882	0.960	0.961
R2 Adj.	0.876	0.956	0.958
RMSE	10.79	0.33	1.00

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001
P-Values between parentheses.

Table 2: Responses of dependent variables to changes in independent variables, calculated from regressions (1) and (2) in Table 1		
1. Percent change* of the real Real/USD exchange rate in response to:		
a. 1% increase in terms of trade	-0.7	
b. 1% appreciation of the real dollar index	1.7	
c. Managed exchange rate regime	-24.4	
d. Fear of Lula	45.5	
e. Covid	39.1	
2. Percentage point change of Brazil's industrialization rate in response to:		
	Short-run	Long-run
a. 10% rise in terms of trade	-0.09	-0.27
b. 1 pp rise in OECD ind. rate	0.56	1.67
c. Plus 1 year (time trend)	-0.04	-0.13
*Calculated at the means of the variables. A positive value indicates depreciation.		

First, consider the regression for the real exchange rate (RER) in column (1) of Table 1. As expected, this variable is highly dependent on Brazil's terms of trade, with a coefficient of -0.7 and an elasticity of also -0.7 (the mean of RER is 109.87, and the mean of the terms of trade is 100.17). As the terms of trade rise by 10%, the real exchange rate appreciates by 7%. The Real/USD exchange rate is even more dependent on the dollar index, with a coefficient of 1.9 and an elasticity of 1.7 (the mean of the dollar index is 101.67). A 10% rise in the dollar index leads to a 17% depreciation of the Real to the U.S. dollar. This shows that the USD value of Brazil's currency is highly sensitive to the dollar's strength in the world economy.

The coefficients of the dummy variables have the expected sign: a 27 pp (or 24%) appreciation during the managed exchange rate period from 1995.1 to 1998.4; a 50 pp (or 46%) depreciation with the fear of Lula from

2002.3 to 2003.1; and a 43 pp (or 39%) depreciation with the Covid crisis from 2020.2 to 2021.4. The percentage changes are calculated at the mean of the RER, which is 109.87. Such sharp fluctuations reveal the sensitivity of Brazil's currency to domestic and external shocks.

We now consider the two regressions in Table 1 for Brazil's rate of industrialization. The only difference in these regressions is that in column (2) the Dutch disease is captured by the terms of trade, while in column (3) it is captured by the fitted RER. For the coefficients of the other regressors, there is little difference in which variable represents the Dutch disease. We'll analyze the coefficients in the regression in column (2), which includes the terms of trade, since this variable was statistically more significant and had a stronger effect on the industrialization rate than the fitted RER. On reflection, this is what we should expect since the RER is affected by variables unrelated to the Dutch disease.

The Dutch disease and the premature deindustrialization hypotheses are statistically significant in the regressions. Consider first the Dutch disease with its effect measured by the coefficient of the third lag of the terms of trade in the regression in column (2), which is -0.009. At the terms of trade mean (= 100.17), a 10% rise in the terms of trade reduces the industrialization rate by .09 pp on impact. This effect needs to be multiplied by 2,97 = [1/(1 - 0,663)] to obtain -0.27 as the long-run effect of the terms of trade on the industrialization rate. In the long run, a 10% rise in the terms of trade reduces the industrialization rate by 0.27 pp. The effect is relevant.

Changes in the OECD industrialization rate have a stronger effect than the terms of trade (but these changes are small compared to the fluctuations in the terms of trade). On impact, a 1 pp reduction in the OECD industrialization rate leads to a 0.563 pp reduction in Brazil's industrialization rate. The long-run effect is 0.563 x 2.97 = 1.67. In the long run, a 1 pp decline in the OECD industrialization rate leads to a 1.67 pp decline in Brazil's industrialization rate. Such a strong effect was already suggested by the data analyzed in section two: Brazil deindustrialized much more than the OECD in the period 1995-2022. This large effect seems difficult to justify in the context of the premature deindustrialization hypothesis alone, which would imply that there is at most a one-to-one correspondence between Brazil's and the OECD's deindustrialization rates. But even with such a high impact, the long-run effect of the 0.5 pp OECD deindustrialization on Brazil is only 0.8 pp. Further research would be needed to determine which domestic factors, such as the high tax burden on manufacturers, would explain the augmented impact of OECD deindustrialization on Brazil.

The single most important variable in explaining Brazil's deindustrialization is the time trend: according to its coefficient in the regression in column (2) of Table 1, the industrialization rate falls by 0.011 pp each quarter, or 0.044 pp per year--and this is on impact. In long-run equilibrium, the effect on the industrialization rate of moving one year ahead is -0.13 pp (=-0.044x2.97). For the 27 years between 1995 and 2022, in the short run, the time trend would lead to a reduction of 1.2 pp (=0.044x27) in Brazil's industrialization rate. In the long run, its negative effect would be 3.5 pp (0.13x27). This is 65% of the 5.4 pp deindustrialization observed in the period.

Finally, there are the seasonal/quarterly dummies. According to these, the industrialization rate is 0.8 pp higher in the 2nd quarter than in the 1st, 1.2 pp higher in the 3rd, and 0.6 pp higher in the 4th. Seasonal variations within the year are very significant. In addition to the negative effect on industrial production of the collective holidays in the Southern Hemisphere summer months of January and February, the trough in the 1st quarter may also be due to the methodology of the IBGE, which imputes most of the agricultural production to this quarter. The peak in the 3rd quarter is probably explained by an acceleration of industrial production in anticipation of higher sales at the end of the year.

4. Conclusions

We investigate three hypotheses about Brazil's deindustrialization from 1995 to 2022: Dutch disease, premature deindustrialization, and (Brazilian-style) Baumol's disease. We capture Dutch disease through terms of trade improvement, premature deindustrialization through the evolution of the OECD deindustrialization rate, and Baumol's disease through a time trend. The time trend stands in for the almost uniformly negative evolution of relative productivity in manufacturing over the period.

Brazilian-style Baumol's disease, as captured by the time trend, is by far the most important factor explaining deindustrialization over the period. It accounts for 3.5 pp, or about 2/3 of the total. [13] The terms of trade also had an impact, rising by about 30% over the period. According to our long-run estimates, this reduced the rate of industrialization by about 0.8 pp. So, Dutch disease is present in the data, but its overall impact is not very large. The OECD deindustrialized little but had a larger effect on Brazil's deindustrialization. In the long run, it explains 0.8 pp of it. Premature deindustrialization explains some of Brazil's deindustrialization, but not more than the Dutch disease.

Table 3 summarizes these results.

[13] Total deindustrialization was 5.4 pp measured by the difference between the industrialization rates in the first quarters of 1995 and 2022, and 5.2 pp measured by the difference between the average values of the industrialization rates in those years.

Table 3: Total long-run effects of independent variables on Brazil's deindustrialization rates, 1995-2022

Total variation	Total effect (pp)
Baumol'disease: 27y	-3.5
Dutch disease (ToT): +30%	-0.8
Premature deindustrialization (OECD deindustrialization): -0.5 pp	-0.8
Sum of long-run effects	-5.1
Total Brazil deindustrialization (pp)	-5.2/-5.4

Sources: see text.

Our results strongly suggest shifting the narrative focus of deindustrialization from GDP shares to relative productivity. Why has Brazilian manufacturing had such a poor relative productivity performance? We have not explored this question econometrically, but we have listed some explanations in the Brazilian literature. Some empirical work suggests a link between industrial productivity losses and higher penetration of industrial imports, which would have disrupted local production chains. However, the econometric evidence points in the opposite direction: import liberalization had a causal positive effect on industrial productivity.

Instead, the problem may be that Brazilian industry has not been sufficiently exposed to the technological benefits and the creative destruction forces of international trade. Brazilian agriculture has experienced a spectacular increase in productivity and is successfully competing with the US and Canada in world markets, which would lend credence to this hypothesis. But other factors, such as relative investment rates and changes in the composition of the manufacturing sector, may have played a role. Our analysis shows that the issue is important enough to warrant further research.

Our econometric exercises uncovered another relevant fact. We found that Brazil's Real/USD exchange rate is indeed much affected by the country's terms of trade, as the Dutch disease hypothesizes. However, other factors were more important, namely, the strength of the dollar in the world economy and domestic and international shocks, such as the Fear of Lula from 2002.3 to 2003.1 and the Covid crisis from 2020.2 to 2021.4. These other factors dampened the effect of the increase in the terms of trade observed during the period on the evolution of the inflation-corrected real/USD exchange rate. This rate fluctuated widely, but since 2011 it has tended mainly to depreciate. One of our regressions captured a small and only marginally significant effect of the Real/USD real exchange rate on the industrialization rate. Appendix B shows that the same results apply to the real effective exchange rate: its effect on the industrialization rate was near zero. These results suggest that the ups and downs of the real exchange rate had little impact on Brazil's deindustrialization from 1995 to 2022[14].

[14] This conclusion is subject to the qualification, investigated by Branstetter and Laverde-Cubillos (2024) for the case of Colombia, that the resource boom of 2005-2011 and the concurrent large appreciation of the peso real exchange rate had a persistent negative effect on the technological development of the manufacturing sector. Similar studies aren't available for Brazil.

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Appendices

Appendix A: Statistical Tests

In this appendix, we provide a series of statistical tests to assess the validity of our regressions. Figures A1 to A4 present the Autocorrelation Functions (ACF) and Partial Autocorrelation Functions (PACF) of our autoregressive estimations [regressions (2) and (3)], examining individual residual autocorrelation in each of the first 20 lags. Table A1 presents the Ljung-Box test results with 10 lags to assess joint residual autocorrelation of regressions (2) and (3). Table A2 includes the Engle-Granger test to determine whether the regression residuals have a unit root, indicating non-stationarity in all regressions.

Fig. A1: Autocorrelation Function – Regression (2) Residuals

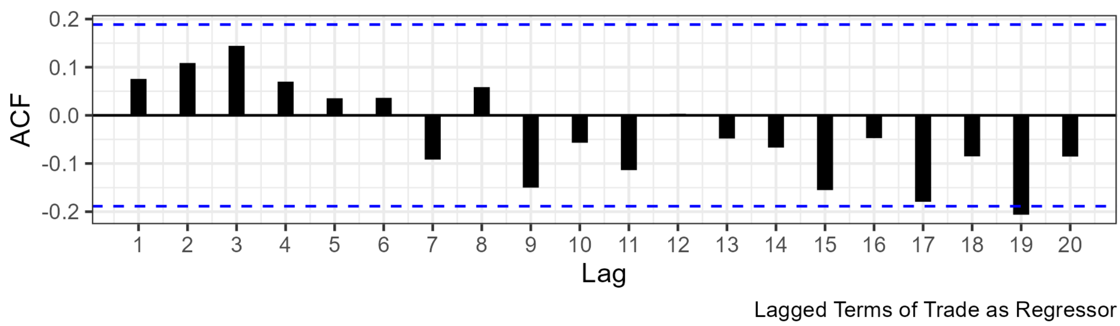


Fig. A2: Partial Autocorrelation Function – Regression (2) Residuals

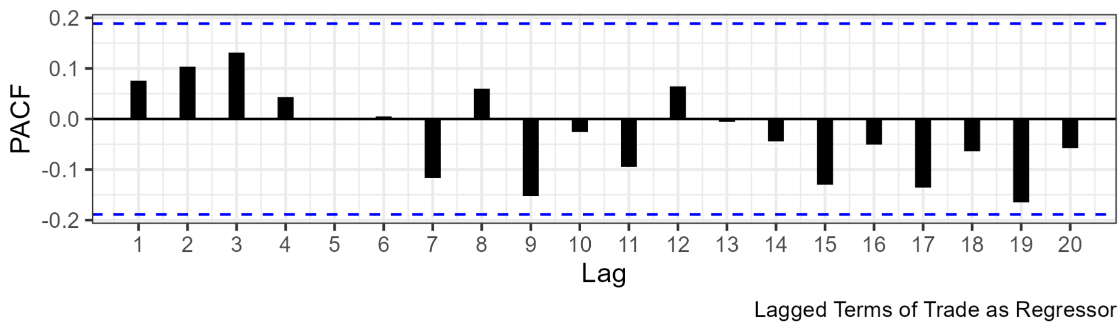


Fig. A3: Autocorrelation Function – Regression (3) Residuals

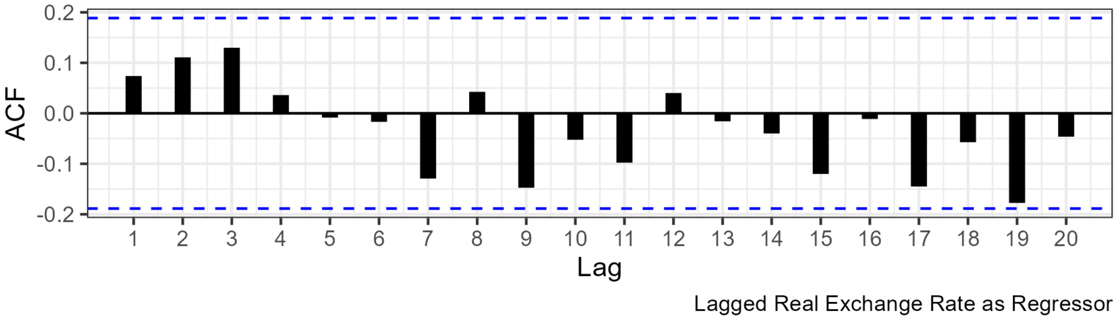
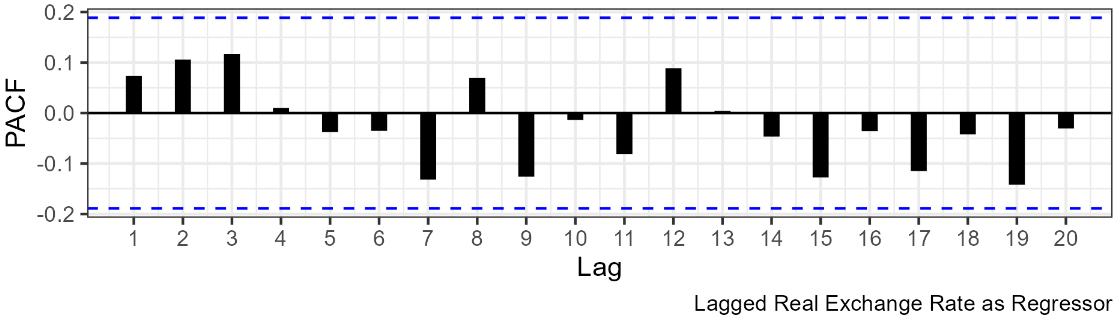


Fig. A4: Partial Autocorrelation Function – Regression (3) Residuals



The figures clearly show that no lag of any regression exceeds the confidence interval bounds of the zero value in the ACF or PACF. Therefore, individual autocorrelation must not be present in the first 20 lags.

Table A1: Ljung-Box tests

	BR Ind. Rate Con. - TOT	BR Ind. Rate Con. - RER
Test Statistic	9.661	9.195
	(0.290)	(0.326)

P-values under coefficients.

The first column of Table A1 presents results for regression (2), which uses the terms of trade as a regressor, and the second column presents results for regression (3), which uses the real exchange rate as a regressor. The p-values for the Ljung-Box tests are greater than 5%, so we can't reject the null hypothesis of no joint residual autocorrelation for 10 lags.

Table A2: Engle-Granger tests

	RER	BR Ind. Rate Con. (TOT)	BR Ind. Rate Con. (RER)
Test Statistic	-3.085	-6.259	-6.217
	(0.003)	(<0.001)	(<0.001)
CriticalValue.1pct	-2.58	-2.58	-2.58
CriticalValue.5pct	-1.95	-1.95	-1.95
CriticalValue.10pct	-1.62	-1.62	-1.62
NumberObs	112	108	108

P-values under coefficients.

The first column of Table A2 presents results for regression (1), the first stage regression of the real exchange rate. The second column presents results for regression (2), which uses the terms of trade as a regressor, and the third column presents results for regression (3), which uses the real exchange rate as a regressor. All test statistics are smaller than their critical values at the 1% significance level. Therefore, we reject the null hypotheses of integrated residuals and conclude that the variables have a non-integrated linear combination, indicating that they are cointegrated.

Appendix B: Real Effective Exchange Rate Specification

In Table B1, the first column shows the first stage regression of an Instrumental Variable (IV) estimation where the real effective exchange rate (REER) is the dependent variable[15]. The coefficients for the terms of trade, the real broad dollar index, and the exogenous shocks aren't very different from those in the RER regression. The R-squared of the first stage regression is also close to that in column (1) of Table 1, indicating that the instruments are similarly strong when applied to the REER.

[15] This is the index of the real effective exchange rate of Brazil's Central Bank.

The second column shows the second-stage regression of the IV estimation, where the 3rd lag of the fitted REER is the independent variable. The coefficient for the REER (=0.004) is not statistically significant at the 5% level, just like the coefficient for the RER (=0.003) in Table 1. The coefficients for the other second-stage regressors are also near those in Table 1.

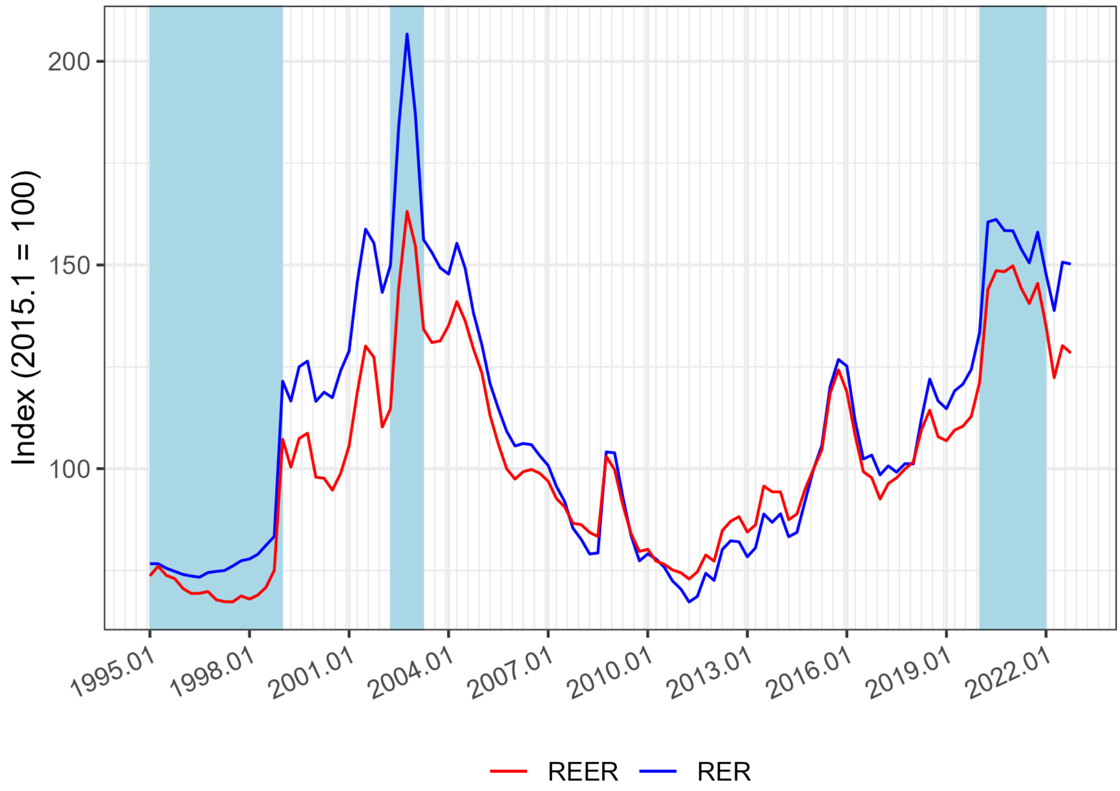
Table B1: REER regression results.

	REER	BR Ind. Rate - Con.
	(1)	(2)
Constant	45.876*	-4.190**
	(0.049)	(0.007)
Terms of Trade	-0.481***	
	(<0.001)	
Real Broad Dollar Index	1.033***	
	(<0.001)	
Dummy Managed	-28.726***	
	(<0.001)	
Dummy Lula	32.135***	
	(<0.001)	
Dummy Covid	41.515***	
	(<0.001)	
1st Lag BR Ind.Rate		0.252*
		(0.027)
2nd Lag BR Ind.Rate		0.144
		(0.222)
3rd Lag BR Ind.Rate		-0.040
		(0.730)
4th Lag BR Ind.Rate		0.282***
		(<0.001)
3rd Lag Fitted REER		0.004 +
		(0.056)
OECD Ind.Rate		0.589***
		(<0.001)
Time Trend		-0.015***
		(<0.001)
2nd Quarter		0.815***
		(<0.001)
3rd Quarter		1.155***
		(<0.001)
4th Quarter		0.568**
		(0.001)
Num.Obs.	112	108
R2	0.820	0.961
R2 Adj.	0.812	0.957
RMSE	10.07	1.00

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001
P-Values between parentheses.

Figure B1 presents the parallel evolutions of the RER and the REER. The exogenous shock periods of the Managed Exchange Rate, the Fear of Lula, and the COVID-19 pandemic are identified in light blue. These external shocks similarly affected the REER and RER.

Fig. B1: Real/USD Real Exchange Rate and Real Effective Exchange Rate, 1995.1-2022.4 (2015.1=100)



Source: Brazil's Central Bank. Blue rectangles cover the shock periods.