Technological intensity in Brazilian industry from 2001 to 2021: sectoral composition and lessons from China's experience for Brazil[a]

Intensidade tecnológica na indústria brasileira de 2001 a 2021: composição setorial e lições da experiência chinesa para o Brasil

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Abstract: This study evaluates the trajectory of Brazilian industry from 2001 to 2021, classifying it according to the four OECD technological intensity levels (low, medium-low, medium-high, and high) and proposing strategies for reindustrialization focused on high-tech sectors. The objective is to evaluate whether the Brazilian economy has undergone a process of reprimarization or negative structural change and, based on the trends identified across these technological tiers, the study proposes alternatives for reindustrialization and a positive structural change. The analysis of value-added employment and exports trends reveals concentration in medium-low technology activities, with low participation from advanced sectors, indicating a regressive specialization in lower value-added activities. Drawing on China's experience anchored in: (1) massive investments in R&D, (2) macroeconomic price controls, and (3) active industrial policy, we discuss alternatives to reverse this scenario

Keywords: Deindustrialization. Structural Change. Dutch Disease.

Resumo: Este estudo avalia a trajetória da indústria brasileira de 2001 a 2021, classificando-a de acordo com os quatro níveis de intensidade tecnológica da OCDE (baixo, médio-baixo, médio-alto e alto) e propõe estratégias para a reindustrialização focada em setores de alta tecnologia. O objetivo é avaliar se a economia brasileira passou

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por um processo de reprimarização ou mudança estrutural negativa e, com base nas tendências identificadas nesses níveis tecnológicos, o estudo propõe alternativas para a reindustrialização e uma mudança estrutural. A análise do emprego de valor agregado e das tendências das exportações revela concentração em atividades de tecnologia médio-baixa, com baixa participação de setores avançados, indicando uma especialização regressiva em atividades de menor valor agregado. Com base na experiência da China, ancorada em: (1) investimentos massivos em P&D, (2) controles macroeconômicos de preços e (3) política industrial ativa, discutem-se alternativas para reverter esse cenário

Palavras-chave: Desindustrialização. Mudança estrutural. Doença Holandesa.

JEL: L52. O33. E66.

1. Introduction

The decline of Brazil's industrial sector over recent decades has been well documented (Feijó; Carvalho; Almeida, 2005). Industry's share of GDP, which peaked at 36% in 1985 (Bonelli; Pessôa, 2010), began falling in the 1980s and dropped to just 11% by 2019, with manufacturing output growing slower than GDP in most years (Morceiro, 2021). This ongoing deindustrialization has brought the need for a national reindustrialization program back to the forefront, now under the banner of the Nova Indústria Brasil (NIB) initiative.

However, one thing the NIB hardly addresses is the technology level of the industry it aims to build. Simply recovering productive capacity is not enough and it is crucial to consider the complexity and technological sophistication of that industry.

If the debate fails to address the level of technological intensity we want for our national industry, we risk cementing a medium-low tech industrial structure. These industries often have lower productivity. Less advanced sectors typically produce less value for every hour worked (Griliches, 1998). Specializing in lower-tech sectors also undermines workforce skills and wages, as these sectors naturally tend to pay lower salaries. Moreover, having a predominance of low-tech industries in the economy makes it harder to generate spillover effects. This means innovations, productivity gains, or new markets do not spread significantly to other sectors, limiting overall economic growth (Hatzichronoglou, 1997).

In this context, the present study seeks to investigate the following question: How has Brazilian deindustrialization unfolded over the last 20 years in terms of technological intensity, and what lessons can be drawn from successful industrialization experiences driven by high-tech sectors? Based on this reflection, the aim is to discuss alternatives not only to halt the ongoing deindustrialization but also to enable a structural transformation of the national industry, with a focus on productive diversification and increasing economic complexity. To address this question, this study uses data from the Brazilian national accounts (IBGE) to profile the country's industrial activity from 2001 to 2021. The focus is on its different levels of technological intensity and how the deindustrialization process has affected each of them.

To better understand the deindustrialization phenomenon, this article compares the Brazilian trajectory with China's industrial development experience.

This comparison is particularly insightful because China presents a contrasting case of sustained industrial growth: its manufacturing value added increased from $625.22 billion in 2004 to $4.91 trillion in 2021 (World Bank, 2026), even though the industry's share of GDP fell from 44.3% to 38.1% over the same period (World Bank, 2026). During this time, Chinese industrial employment rose from 22.3% to 31.53% (World Bank, 2026). Moreover, manufactured goods now account for 93% of all Chinese exports (World Bank, 2026), with the share of medium- and high-tech exports rising from 47% in 2001 to 62% in 2021 (World Bank, 2026). In absolute terms, high-tech exports alone grew from $343 billion in 2007 to $825 billion in 2021 (WITS, 2024).

This massive and sustained expansion was underpinned by massive and sustained investments in R&D, rising from US$136 billion in 2007 to over US$780 billion in 2023 (OECD, 2025), along with the strategic management of macroeconomic prices and industrial policies targeted at high-technology and strategic sectors, together with strict capital controls that shielded its domestic economy from financial volatility (Naughton, 2021).

This discussion aims to contribute to a more informed debate on Brazil's economic development by moving beyond short-term fixes and commodity-driven growth. It highlights the critical need for a comprehensive industrialization strategy; one that fosters long-term innovation, enhances global competitiveness, and ensures environmental and economic sustainability.

To ground this comparative analysis, the study is structured in five sections, beginning with this brief introduction, followed by a theoretical review. This section defines key concepts, such as the different levels of technological intensity in industry, low-medium, medium, medium-high, and high, based on OECD taxonomy parameters (Galindo-Rueda; Verger, 2016), and explores how these levels influence societal development, their economic impacts, and their spillover effects. The methodology applies this theoretical framework to the context of the Brazilian industrial sector and its recent trajectory, aiming to build a profile of the national industry. This profile will then allow, in the results and discussion section, the identification of the sector's structural weaknesses, enabling a deeper analysis of Brazilian deindustrialization. Finally, based on this diagnosis, possible paths for reindustrialization are discussed. The goal is not only to recover industrial capacity but also to build a more complex, diversified, and technologically advanced productive structure.

2. Industry, structural change and deindustrialization in Brazil

The manufacturing industry is widely recognized as the primary engine of economic development and global income convergence. Rodrik (2013) emphasizes its unique role by demonstrating that manufacturing exhibits unconditional productivity convergence, allowing developing nations to bridge the gap with advanced economies regardless of institutional quality. Complementing this view, McMillan, Rodrik and Verduzco-Gallo (2014) argue that structural change, the movement of labor from traditional sectors to high-productivity industry, is fundamental for sustainable growth. Furthermore, the debate presented by Lin and Chang (2009) reinforces that industrialization is essential for upgrading a country's economic structure.

Echoing these modern perspectives, Kaldor's laws (Kaldor, 1966) in *Causes of the Slow Rate of Economic Growth of the United Kingdom* provide the essential theoretical basis for viewing industry as the main engine of growth. The three key reasons for this unique importance are: (i) its stimulation of research and development; (ii) its production of final goods with higher demand elasticity compared to primary products; and (iii) its greater complexity, especially in high-tech industries.

Investment in research and development which we will refer to as R&D plays a fundamental role in economic growth. It not only boosts production capacity within industry, but also creates spillover effects that raise productivity in other sectors and in the economy as a whole (Jones; Williams, 2000). These spillovers occur when research results such as technical knowledge and developed technologies are replicated by other sectors, further stimulating innovation and productive efficiency. This relationship highlights an important connection between the growth rate of the capital stock and the rate of labor productivity known as the Kaldor-Verdoorn Law. Industrial investment thus creates a positive externality by boosting the productivity of both capital and labor.

From the perspective of demand elasticity, manufactured goods unlike commodities and raw materials have higher demand elasticity. In practical terms, this means that as consumers' income rises, the demand for industrial goods tends to increase more than proportionally (Prebisch, 1950; Singer, 1950).

In contrast, primary products face relatively inelastic demand. Even with significant gains in productivity and competitiveness, the increase in demand for these goods is limited. As a result, in commodity-based economies, productivity gains often lead to falling prices without corresponding increases in demand. This ongoing price drop forces producers to adopt ever more efficient and productive methods in an attempt to remain competitive, a relentless race where innovation often becomes a cycle of lowering prices. However, smaller producers and those in peripheral countries, such as Brazil with limited access to new technologies and low capacity to invest often end up suffering the negative effects of falling prices without being able to benefit from technological advances. This dynamic tends to make the sector increasingly concentrated and unequal, with severe negative impacts for commodity-dependent economies (Prebisch, 1950; Singer, 1950).

In this sense, studies such as Gala, Rocha and Magacho (2018) show that economic complexity, the structure of production and the sophistication of exported products is a decisive factor in economic development. For these authors, industrialization should be analyzed through the lens of the diversity and ubiquity of its products, which define its complexity. Thus, economies that export more complex goods such as automobiles, computers, and integrated circuits, tend to have higher *per capita* income and a higher level of development. The production of such goods requires a larger and more qualified workforce and generates significantly more added value. Hausmann *et al.* (2011) reinforce this view by arguing that industrial complexity not only reflects the level of development but also acts as a vital engine for sustained national growth.

It is important to recognize that industry is not homogeneous. On the contrary, there is significant diversity among different industrial sectors and their respective contributions to the economy. Understanding this varied productive structure is essential to grasp how industry, in its multiple facets, affects growth and innovation.

A productive structure refers to how a country's economy is organized. It includes the mix of its main sectors, agriculture, industry, and services, and how resources like capital, labor, and technology are distributed across them. It also involves how value chains are linked, as well as the economy's capacity for innovation and competitiveness. This structure can be described by how diversified or specialized it is, the level of technology used, how integrated it is into global trade and value chains, and how productively it can turn inputs into goods (Kupfer; Rocha, 2015).

In simpler terms, the productive structure can be understood as the makeup of key economic aggregates, such as demand, trade, production, and employment. From a quantitative perspective, it can refer to ratios derived from technological or behavioral relationships like input-output coefficients or the aggregate savings rate (Syrquin, 1998).

Based on this idea, structural change refers to shifts in a country's productive structure. It involves moving resources like labor and capital from lower-productivity sectors into activities that have greater potential to generate value. This process is essential for long-term economic growth because it does not just lead to one-time productivity gains. Instead, it creates a cumulative cycle of progress, where successive improvements lead to new gains in efficiency. In this way, structural change plays a central role in economic development, driving the transition toward more dynamic and innovative sectors (Tregenna, 2015). It is worth noting that different models used to measure structural change rely on different economic variables (Syrequin, 1998).

The idea of structural change is closely linked to the concept of economic complexity. A transition toward more dynamic and productive sectors can only be sustained when the economy develops the ability to produce diverse and "rare" that is, non-ubiquitous goods and services. However, this kind of productive sophistication does not happen automatically. It depends on the economy's ability to absorb advanced knowledge and integrate innovative processes into its productive and R&D structure (Castigo; Manuel; Macombe, 2022).

An important metric in this context is technological intensity, which refers to the level of knowledge and innovation embedded in a sector's production. It can be measured by the ratio between R&D spending and the sector's value-added (Zawislak; Fracasso; Tello-Gamarra, 2013). Based on the ratio of R&D spending to value-added, the Organization for Economic Cooperation and Development (OECD) divides economic sectors into five distinct categories of technological intensity. Low technology: Sectors with a ratio below 0.5; Medium-low technology: Sectors with a ratio between 0.5 and 1.8; Medium technology: Sectors with a ratio between 1.8 and 4; Medium-high technology: Sectors with a ratio between 4 and 20 and; High technology: Sectors with a ratio above 20.

It is important to note that the first category (low technology) includes only non-manufacturing sectors, such as certain services, agriculture, and construction. High technological intensity, in particular, plays a key role in economic growth. Industries in this category often grow the fastest because they are more efficient and innovative compared to industries in other categories, and employments generally show higher indicators. This not only results in better wages for employees in these industries but also creates positive spillover effects on related sectors through the diffusion of technology (Hatzichronoglou, 1997).

These differences between industrial sectors and their respective technological intensity classifications are also reflected in patterns of deindustrialization. Colombo, Felipe, and Sampaio (2021) observed that, in general, deindustrialization has affected Brazilian manufacturing in varied ways. Sectors with medium-high and high technological intensity have faced more severe impacts, reflected mainly in their trade balance and physical production trends.

Deindustrialization is typically seen as a structural shift in an economy. It involves a significant movement of workers away from the industrial sector often to the service sector. This leads to a loss in industry’s share of total employment, and usually also its contribution to GDP and exports (Rowthorn; Wells, 1987, *apud* Nassif, 2008). More recent studies, like Tregenna (2015), argue it should be understood as a sustained process where manufacturing declines in both employment and its share of GDP.

This process can happen in two very different contexts. In advanced economies, it can be a natural result of technological progress and strong productivity growth in manufacturing. In developing economies, however, it is often driven by factors like international competition or weak economic policies in a premature process (Rowthorn; Ramaswamy, 1999).

It’s important to note that deindustrialization isn't always a bad thing. In wealthy countries, the decline in manufacturing jobs can be a sign of economic dynamism. As productivity in manufacturing grows faster than in other sectors, the prices of industrial goods fall and demand for them rises. This productivity growth is often fueled by new technology and leads to fewer jobs being needed in manufacturing (Rowthorn; Ramaswamy, 1999).

In Brazil's case studies on deindustrialization became more common from the mid-1990s onward, though early findings were mixed. Some researchers felt there was not enough clear evidence to call it premature deindustrialization (Nassif, 2008). Others, however, pointed to a worrying decline linked to neoliberal policies and a broader weakening of industry across Latin America, even suggesting symptoms of Dutch Disease (Bresser-Pereira, 2007).

Over time, evidence for a Brazilian deindustrialization process grew stronger. Esposito (2017) showed signs of manufacturing contraction and the weakening of its key structural pillars, like productive linkages and value-added capacity. More recent work confirms this trend, noting industry's declining role in GDP, formal job creation, and the number of industrial firms, with potential harm to economic dynamism (Gelatti *et al*., 2020). The current debate now focuses on better understanding the nature of this process distinguishing between relative deindustrialization (Colombo; Felipe; Sampaio, 2021) and broader structural change (Araújo; Peres; Araújo, 2023).

Deindustrialization in Brazil has unfolded in a unique way. Cruz and Santos (2011) confirmed a real loss of industrial jobs between 1990 and 2009. However, this decline was not uniform. While major metropolitan areas like Rio de Janeiro and São Paulo saw significant job losses, there was smaller growth in industrial jobs in more peripheral regions, like the Northeast and Central-West. The net result was an overall contraction, felt most strongly in the industrial heartlands of the South and Southeast.

Furthermore, Cruz and Santos (2011) showed that the job growth in peripheral regions during the 1990s and 2000s was driven by industries with lower technological content. This contrasted with the more established industrial regions (South and Southeast), which managed to preserve jobs in more technologically advanced sectors. The conclusion is that Brazil did not just deindustrialize it also experienced a loss of technological intensity, resulting in an industrial base that is less complex and less tech-driven.

This pattern is confirmed by looking at Brazil's industrial productivity trend. Compared to U.S. productivity, Brazil's level fell systematically from 30% in 1980 to 20% in 2008. This suggests that more productive, high-tech industrial sectors are losing ground in Brazil's industrial structure to lower-tech, lower-productivity sectors (Nassif; Feijó; Araújo, 2015).

The weakness of Brazil's more advanced sectors reflects a widely discussed competitive disadvantage. On the international stage, the country's emerging industries are still seeking scale and capital face off against established competitors with greater financial flexibility. In an often adverse macroeconomic environment, this asymmetry becomes critical. International competitors can easily absorb temporary losses to neutralize emerging rivals, effectively stifling local innovative sectors before they can mature. This dynamic reinforces a regressive specialization in Brazil's industrial structure.

3. Empirical Strategy

Brazilian macroeconomic framework has been largely defined by the "macroeconomic tripod," a policy arrangement established in 1999 that combines inflation targeting, floating exchange rates, and primary fiscal surplus targets (Oreiro; D'Agostini, 2016). While initially designed to ensure price stability and debt sustainability, evidence suggests the management of this regime often reinforced a trend of high real interest rates and persistent real exchange rate overvaluation (Oreiro; D'agostini; Gala, 2020). Specifically, the transition to a floating exchange rate system ended the previous fixed anchor but did not prevent chronic currency appreciation, which contributed to "premature deindustrialization" and a loss of competitiveness in the manufacturing sector (Bresser-Pereira, 2020; Oreiro; D'Agostini; Gala, 2020).

In response to these structural imbalances, the Brazilian government under Dilma Rousseff introduced the New Economic Matrix (*Nova Matriz Econômica*). This proposal sought to address the tripod's limitations by lowering the SELIC interest rate and promoting a more competitive exchange rate through systematic market interventions (Souza; Nascimento, 2019). To stimulate the manufacturing sector and counteract deindustrialization, the strategy combined expansionary fiscal policies, such as tax exemptions and subsidized credit via public banks, with lower energy costs and protectionist industrial measures. However, while intended to restore growth and competitiveness, this departure from the traditional framework ultimately led to a deterioration of fiscal transparency and failed to sustain long-term investment, eventually contributing to the economic instability it aimed to resolve (Reis, 2016).

To empirically examine the structural effects of these policy regimes, the methodology of this study is based on applying the OECD's classification of technological intensity (Galindo-Rueda; Verger, 2016) to the 51 economic sectors as disaggregated by the Brazilian Institute of Geography and Statistics (IBGE). The selection of this classification, while inherently arbitrary, is justified by its development by a recognized international institution specifically for the study of technological intensity across different economies. Sectors belonging to manufacturing were categorized according to the OECD levels of technological intensity – low, medium-low, medium-high, and high – while the remaining sectors were grouped into a single general trend.

Based on this categorization, separate trend charts were developed for each of the three perspectives commonly used to examine deindustrialization: value-added, employment and exports. This allows us to observe their dynamics over time.

The period considered is from 2001 to 2021. The choice of this period is justified by its focus on the first two complete decades following the consolidation of Brazil's macroeconomic tripod and the floating exchange rate regime implemented in 1999. The year 2021 serves as the endpoint due to data availability at the time of the study. All data were adjusted to constant December 2024 prices using the IPCA (National Consumer Price Index), with value corrections sourced from the Central Bank of Brazil.

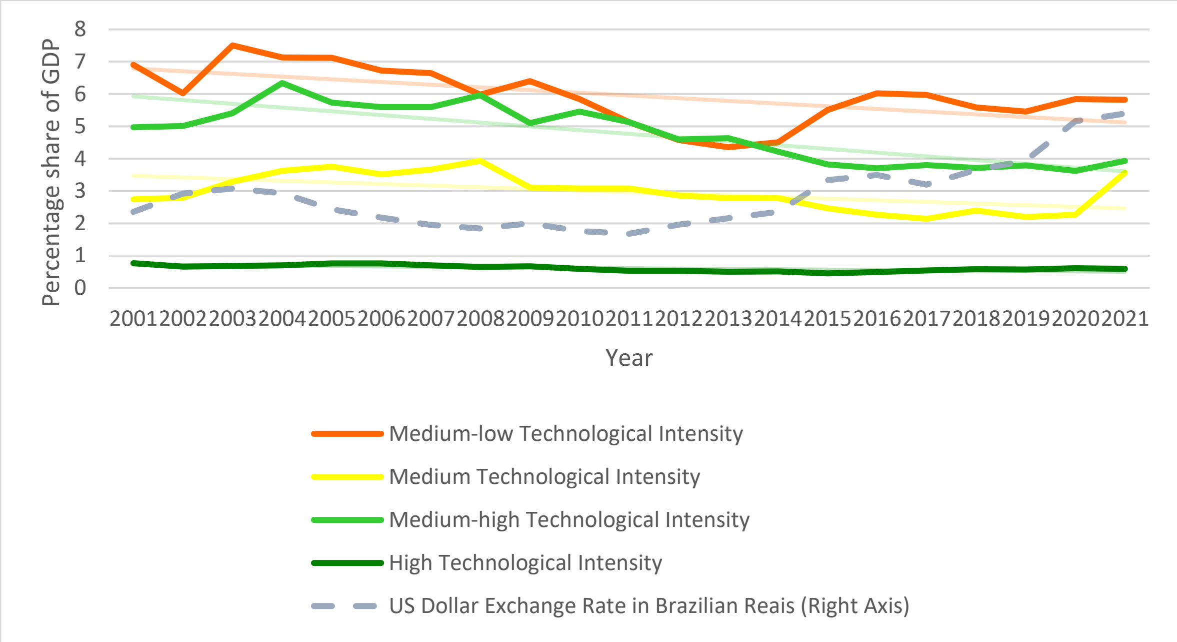
4. Results and Discussion

4.1 Value-Added

The value-added is a fundamental dimension to capture changes in a country's productive structure and very relevant for analyzing the relative contributions of industry compared to other sectors. As recent approaches to the deindustrialization debate suggest (Tregenna, 2015), observing the evolution of value-added helps identify possible losses in the economic importance of the manufacturing sector.

Figure 1 illustrates the trends in value-added over time, broken down by the different levels of technological intensity in industry from 2001 to 2021.

Figure 1 – Percentage share in value-added by technological intensity level (2001-2021)



Source: Elaborated by the authors with data from IBGE.

While value-added in the high-tech sector remained relatively stable over the whole period (Figure 1), a negative shift can be observed starting in 2003. This movement coincides with the phase of currency appreciation for the Brazilian real between 2003 and 2011 (Banco Central do Brasil, 2025), which likely reduced the competitiveness of national industry. This effect was particularly strong in higher-tech sectors, which are more sensitive to international competition in the Brazilian context.

In contrast, the medium-low tech industry managed to regain considerable momentum between 2014 and 2016 (Figure 1), precisely during a period of currency depreciation. One possible explanation for this responsiveness is that, unlike the more advanced sectors, this industrial segment was already more consolidated in the country. This established position, with accumulated productive and commercial capabilities, may have granted it greater resilience to withstand adverse exchange rate periods and more agility to seize opportunities even if this recovery might signal a process of reprimarization of the export basket. This suggests that, despite some dynamism, growth may be linked more to less technologically sophisticated sectors, such as processed foods and mineral products, than to a structural advance of industry.

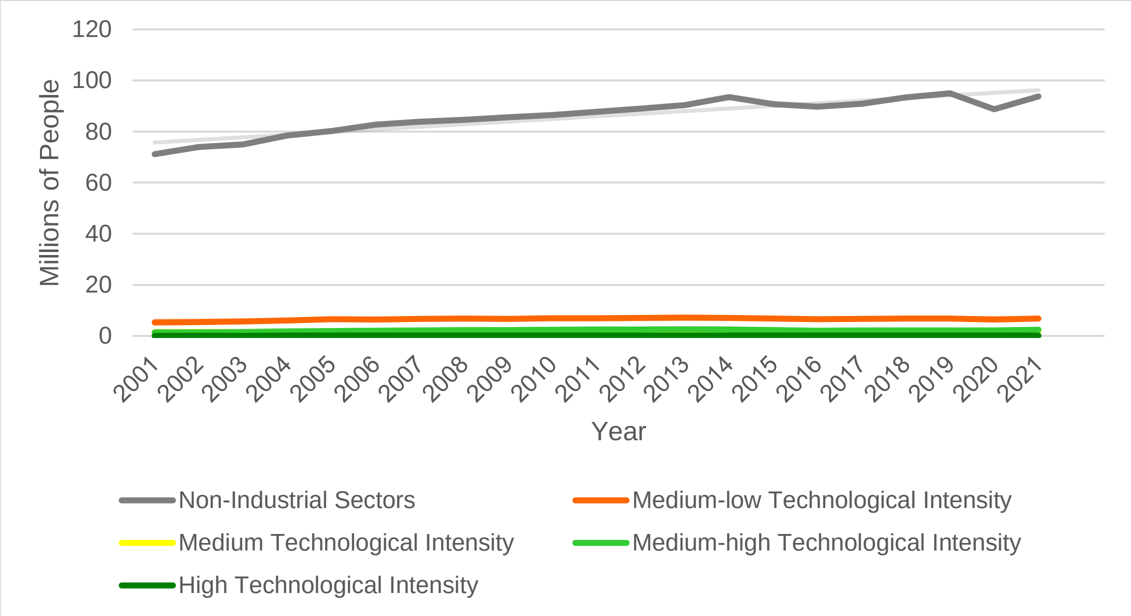
This trend aligns with the sectoral heterogeneity of industry and the effects of so-called Dutch Disease, which impact medium and high-tech sectors more intensely, harming their competitiveness and contributing to a regressive reconfiguration of the productive structure. On the other hand, medium and medium-high tech segments only showed clearer signs of recovery from 2020 onward, with the medium-tech industry standing out (Figure 1). Still, by the end of the period analyzed, all technological levels had recorded a contraction, revealing a persistent deindustrialization trend that cuts across different levels of productive sophistication.

It is important to highlight that, despite these internal transformations, the overall share of industry in GDP when compared to other sectors remained relatively constant over the 21 years, declining by roughly two percentage points, from 15.37% in 2001 to 13.91% in 2021 (Figure 1). This indicates that industry as a whole did not dramatically decrease its share, but rather changed its internal composition, with a likely shift toward less technology-intensive segments, a concerning scenario for a country seeking productive diversification and long-term productivity gains.

4.2 Employment

Deindustrialization, in its most classic sense, is associated with the relative loss of employment in the manufacturing sector. Based on this perspective, Figure 2 shows the evolution of employment categorized by technological intensity in different non-industrial and industrial sectors in the Brazilian economy between 2001 and 2021.

Figure 2 – Total occupations in the economy by technological intensity level, in millions of people (2001-2021)



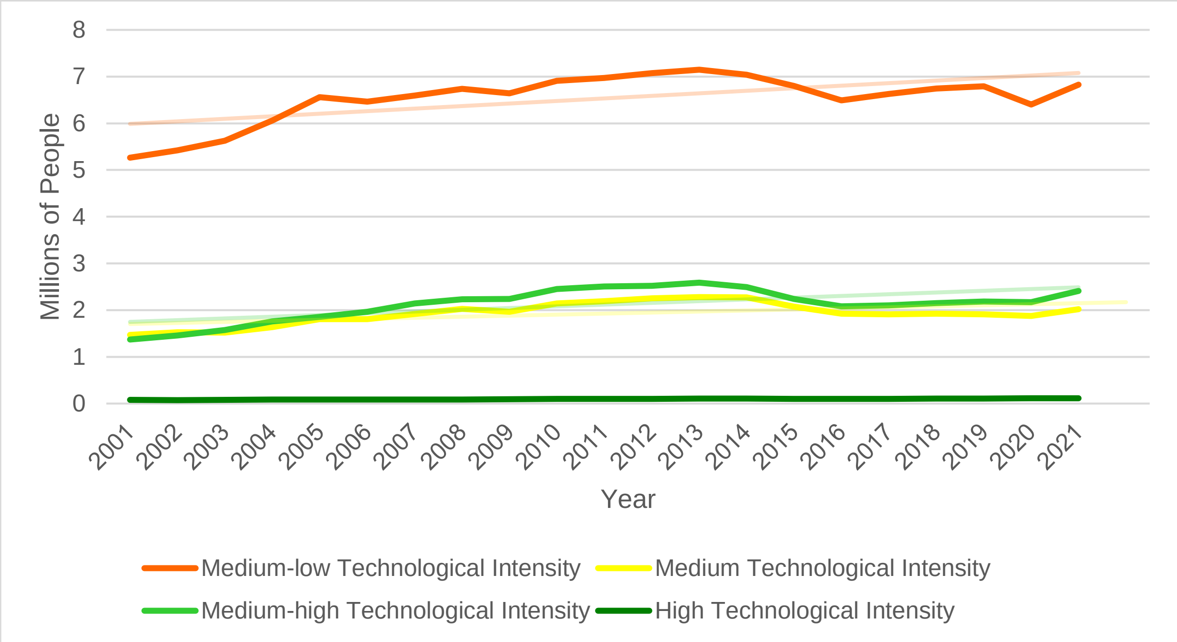
Source: Elaborated by the authors with data from IBGE.

Figure 2 shows that most jobs are concentrated in the non-industrial sectors, represented by the gray line, which shows values much higher than the other categories and consistent growth over time. In contrast, the different levels of technological intensity in industry have a significantly smaller share of total employment.

Furthermore, it can be seen (Figure 2) that employment in industrial sectors grows much more modestly compared to the non-industrial sector. This indicates a decline in the relative share of industrial employment. In other words, even if there is some absolute growth, its share of total jobs is decreasing because its growth rate is lower.

Given the general employment trends in the economy, the analysis now turns specifically to employment in the manufacturing industry, focusing on the distribution of jobs across the different levels of technological intensity (Figure 3). This breakdown makes it possible to identify which industrial segments have been most affected over time, revealing internal dynamics within the sector that may be linked to distinct patterns of modernization, competitiveness, and integration into the global market.

Figure 3 – Total occupations in the industry by technological intensity level, in millions of people (2001-2021)



Source: Elaborated by the authors with data from IBGE.

The employment trends across different technological intensity levels (Figure 3) did not show major differences during the period analyzed. A small decline in 2013 was observed, followed by stabilization in 2016 and a recovery in 2020, with all levels moving in a similar pattern.

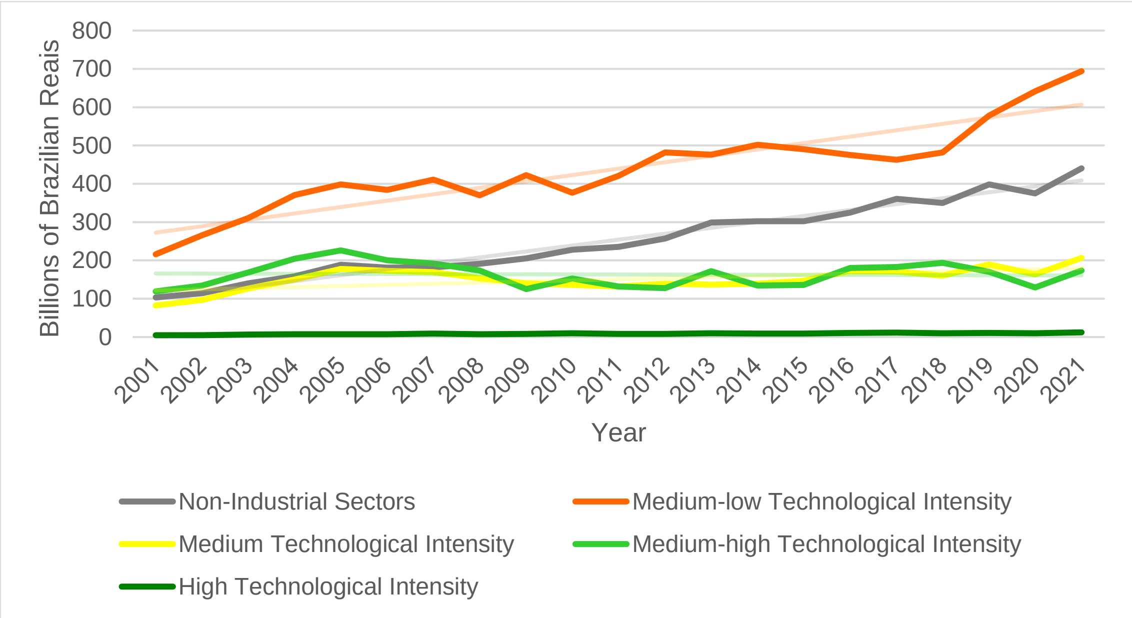
These fluctuations (Figure 3) suggest a common dynamic in the labor market, without distinct reactions from each intensity level to specific events, such as the 2014 economic crisis or the 2020 pandemic and its aftermath. It is important to highlight, however, the strong concentration of employment in medium-low technology industries, which remained significantly higher than all other industrial groups throughout the entire period.

4.3 Exports

Different views about deindustrialization often combine the analysis of industrial employment with other indicators, such as industry's share of exports (Rowthorn; Wells, 1987 *apud* Nassif, 2008). This broader perspective aims to capture not just the reduction in industrial jobs, but also shifts in the sector's role in the global market and its ability to generate value through foreign trade.

Based on this approach, Figure 4 examines the evolution of manufacturing exports, by levels of technological intensity, from 2001 to 2021. The goal is to identify possible signs of the sector losing or gaining prominence in international trade.

Figure 4 – Exports by technological intensity level, in billions of Brazilian Reais (2001-2021)



Source: Elaborated by the authors with data from IBGE.

Despite fluctuations over the period (Figure 4), a consistent growth trend can be seen in exports from medium-low technology industries and from non-industrial sectors, such as services and agriculture. In contrast, sectors with medium, medium-high, and high technological intensity maintained relatively stable levels. Notably, there was a slight contraction in medium-high intensity and a modest advance in medium intensity.

A decrease in the trend in 2005 modestly affected all levels (Figure 4), but the subsequent recovery was uneven. While medium-low technology industries and other non-industrial sectors rebounded relatively quickly, the more technology-intensive sectors only managed to stabilize their export volumes around 2009, with minor fluctuations in the following years. A new decline in 2019 was followed by a noticeable recovery across all intensity levels during 2020, although this did not reverse the previous pattern.

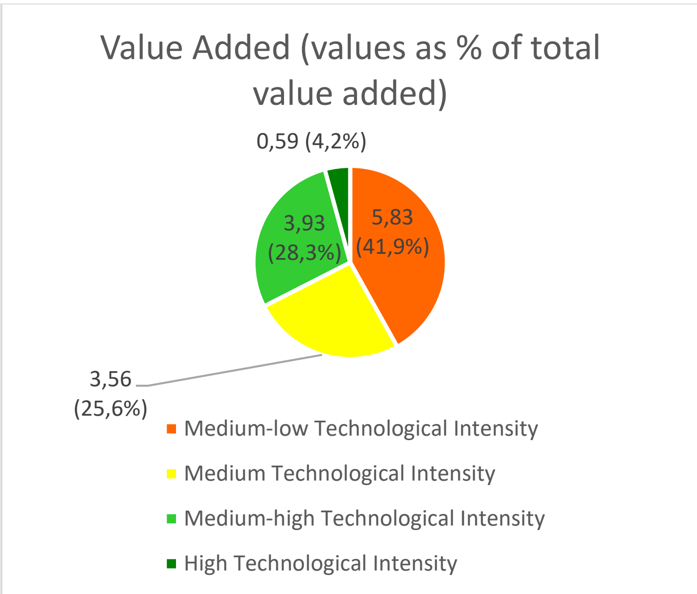
This trajectory reveals a concerning trend, the dynamism of Brazil's industrial exports has indeed become concentrated in the least technology-intensive sectors and outside of industry, suggesting a case of regressive specialization. The relative loss of prominence by higher-technology sectors undermines the potential for productive sophistication and generating higher value-added in foreign trade.

4.4 Overall analysis for Brazilian industry

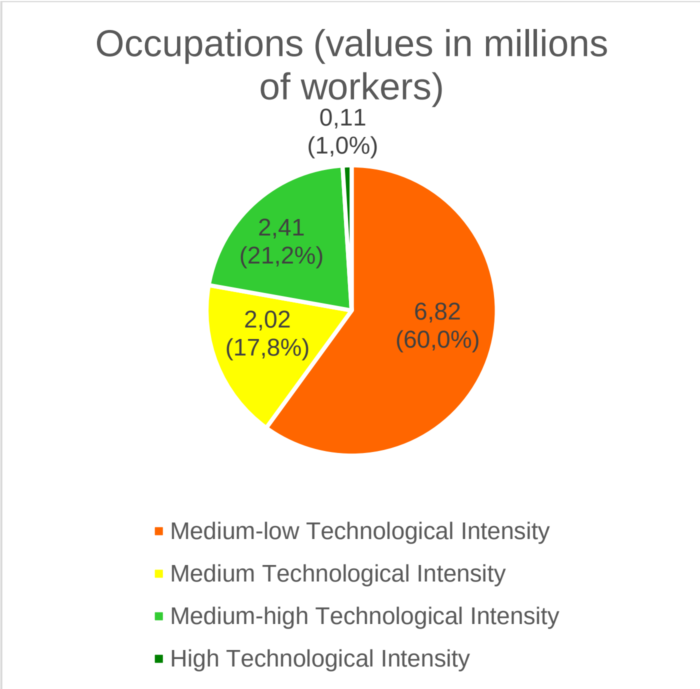
After examining the individual trends in value-added, employment and exports, a synthesized view of the recent structure of Brazilian industry is presented (Figure 5). The goal in this analysis is to provide a snapshot of the sector's internal dynamics, highlighting the distribution across different levels of technological intensity and allowing for a clearer assessment of its productive configuration in the most recent period.

Figure 5 – Percentage Composition of the Brazilian Industry in 2021 by Value-Added (A), Occupations (B) and Exports (C)

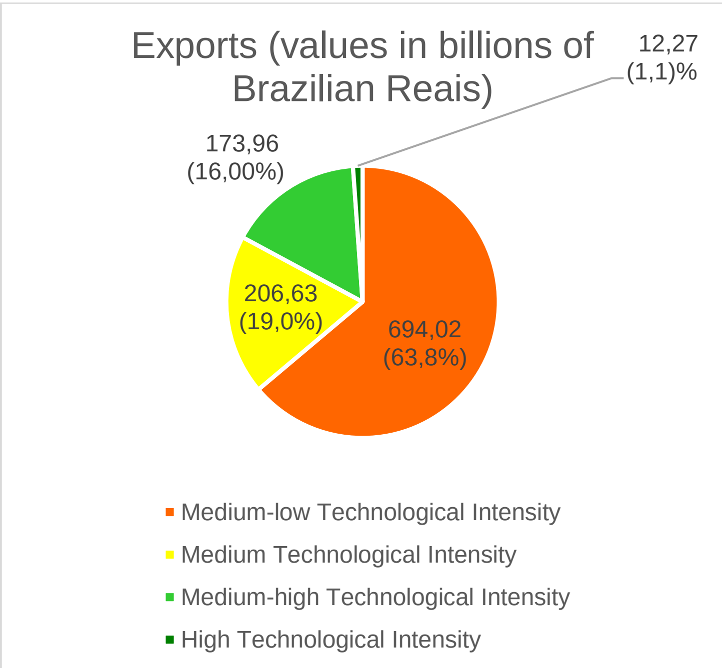
(A)



(B)



(C)



Source: Elaborated by the authors with data from IBGE.

The composition of the national industry (Figure 5) reveals a significant concentration of both employment and exports in sectors classified as medium-low technological intensity. This indicates that the majority of the workforce and external sales are linked to activities with lower productive complexity.

Industries of medium and medium-high technological intensity show a relatively balanced share between employment and exports, demonstrating a considerable presence in both employment and trade, yet still falling short of a desirable level. In contrast, industries in the high-tech category have only a marginal share in both employment and exports. This reveals not just their low integration into the productive structure, but also the absence of effective industrial policies aimed at promoting these sectors.

Regarding value-added (Figure 5 A), a different dynamic is observed. The medium-high and high-intensity levels account for a more significant portion. Conversely, the medium-low intensity sectors, despite leading in employment and exports, contribute less to wealth creation, suggesting lower productivity and sophistication. This contrast highlights the reduced capacity of these less tech-intensive industries to generate added value compared to their higher-tech counterparts. In other words, increasing industrial value-added depends on strengthening the more technology-intensive segments.

In contrast to the Brazilian industrial structure, where medium-low tech sectors dominate employment and exports with limited value-added generation, the Chinese experience demonstrates a successful trajectory of productive upgrading. While Brazil's high-tech industry holds only a marginal share in both employment and exports, China has achieved a remarkable expansion in its medium- and high-tech sectors, with their share of exports rising to 62% by 2021. Furthermore, whereas Brazil's medium-low tech industries contribute less to wealth creation despite leading in employment, China's manufacturing value added has grown substantially, reaching $4.91 trillion, alongside an increase in industrial employment. This contrast underscores that Brazil's industrial structure remains concentrated in less sophisticated activities, while China has effectively pursued a path of technological intensification, resulting in greater value-added generation and a more dynamic insertion in global trade.

5. Discussions and lessons from China's model

Given Brazil's current context marked by deindustrialization and declining technological sophistication, reversing this trend is not only urgent but strategically vital to prevent the deepening of structural imbalances in the country.

On the other hand, the Chinese experience offers valuable lessons. Since adopting its reform and opening-up policy in 1978, China has prioritized an innovation-based development strategy, channeling massive investments in R&D to move from secondary innovation (adapting foreign technologies) toward original innovation. This sustained effort which raised China's R&D spending from US$136 billion (2007) to US$781 billion (2023) (OECD, 2025) has enabled the country not only to close the technological gap but to take the lead in areas such as artificial intelligence, 5G, and clean energy. Seizing the window of opportunity created by ever-shorter technology cycles, China has transformed its industrial base into a high-tech ecosystem where productivity gains, cross-sector spillovers, and productive complexity reinforce each other (Wu; Wu, 2023).

Beyond heavy investment in R&D, China's industrial success relied on consistent macroeconomic management aimed at encouraging productive investment and competitiveness, that is, steering key economic prices to create a supportive environment for maintaining and expanding its industrial base. A central tool of this strategy was maintaining a competitive exchange rate, which shielded domestic industry while boosting exports. At the same time, low real interest rates and satisfactory profit margins ensured continued investment, while inflation control combined with wage policies that linked pay increases to productivity growth helped expand the domestic market sustainably (Milaré, 2020). This policy mix was essential to fostering a cycle of investment and industrial modernization that sustained growth of about 8% per year, while during the same period Brazilian growth was approximately 3% (World Bank, 2021).

A third pillar was equally crucial in China's industrialization strategy: an active and well-designed industrial policy, consolidated with the adoption of the Innovation-Driven Development Strategy (IDDS) in 2016. Unlike Brazil's Nova Indústria Brasil (NIB) plan which lacks a clear strategic focus on high-tech industries, the Chinese IDDS marked a profound shift in the Chinese state's approach, elevating industrial policy from a sectoral tool to a national strategy for responding to the global technological revolution. Under this new framework, state intervention came to be justified not only by traditional growth objectives but by the transformative potential of general-purpose technologies (such as AI and clean energy), capable of generating positive spillovers across the entire economy. The IDDS also articulated a strategic transition; facing the exhaustion of its comparative advantage in low-cost manufacturing, China redirected its resources human, institutional, and financial toward high-tech, high-value-added sectors, combining its demographic scale with a historical emphasis on education and diligence (Naughton, 2021).

The Chinese strategy built on R&D, macroeconomic price management, and proactive industrial policy led, in 2024, to an increase in economic activity, supported by strong performance in investment, consumption, and foreign trade. Highly tech-intensive sectors such as electric vehicles, solar panels, and lithium-ion batteries have become key drivers of growth, raising the share of "new industries" in GDP and advancing the country's technological diversification. At the same time, investments in high-tech fields, leadership in industrial exports, and the geographical diversification of trade flows demonstrate that China is not only expanding its productive sophistication but also repositioning itself in global supply chains with greater strategic autonomy (Liang, 2025). This reflects a coherent and cumulative process in which economic policy instruments do not merely respond to short-term challenges but actively shape the development path itself.

Implementing similar policies in Brazil would face significant structural and institutional hurdles. Unlike China, which demonstrates strong capacity for long-term strategic planning and state coordination, Brazil contends with political discontinuity, fiscal constraints such as the former spending cap, now restructured as a new fiscal framework and weak coordination across different levels of government. Moreover, the absence of a consistent industrial policy oriented toward high-tech sectors limits the impact of Brazil's already modest R&D investment (De Negri *et al*., 2020).

Furthermore, the effectiveness of monetary and exchange rate policies in Brazil is compromised by the country's specific financial system design. Empirical evidence indicates that central bank interventions in Brazil have been largely insignificant in controlling exchange rate volatility, a sharp contrast to the effectiveness seen in other BRICS nations like China (Anjaly; Deo, 2025). This ineffectiveness is closely linked to the high degree of bank concentration in the Brazilian interbank market, where a "rich-club" of large banking institutions dominates the network's core (Silva *et al.*, 2015). Such structural concentration can distort the transmission of policy signals, as the system's performance is heavily dependent on a few interconnected players rather than broad market mechanisms. Research suggests that monetary policy and its transparency function more effectively in environments with greater competition, as banks in less concentrated market structures are more responsive to policy shifts and uncertainty (Ge; Liu; Zhuang, 2022).

Exchange-rate volatility, high real interest rates, and the fragile link between science, technology, and production complicate the creation of a truly advanced, technology-intensive productive ecosystem. Therefore, while the lessons from China are valuable, adapting them to the Brazilian context will require not only political will but deep institutional reforms that enable the state to design and implement development policies in a stable, strategic, and long-term manner.

6. Conclusion

This article addressed how Brazilian deindustrialization has unfolded over the last 20 years, revealing a concerning trend of regressive structural change. The data from 2001 to 2021 indicates that this process is characterized by a high concentration of employment and exports in medium-low technology-intensive industries, sectors generally tied to commodity production chains. This shift signals not only a weakening of the national productive base but also a dangerous pattern of economic re-primarization.

This process is clarified by the link between exchange rates and industrial performance. While causality remains complex, data shows that currency overvaluation coincides with systematic declines in industrial value-added. Conversely, subsequent devaluations yield an asymmetric recovery, restricted to medium-low technology sectors. This trajectory exposes a perverse selection dynamic, whereby sustained currency overvaluation progressively eliminates more sophisticated industrial sectors, leaving only those endowed with natural comparative advantages, notably commodity-related exports.

In light of China's industrialization experience discussed here, it becomes evident that reversing this trend in Brazil requires an integrated, sustained long-term strategy. This strategy must combine robust and continuous investment in R&D, rigorous management of core macroeconomic prices alongside a further fragmentation of the banking sector, and an active industrial policy focused primarily on high-technology sectors. Only the effective coordination of these pillars, over a long-term horizon, can enable the construction of a productive ecosystem capable of promoting real productivity gains, technological diversification, and greater sophistication of Brazil's industrial structure. Without this strategic coordination, the country risks deepening its reliance on primary goods and technological backwardness, compromising its economic development and international competitiveness.

The article argues that reversing this structural regression requires a coherent developmental strategy that aligns industrial policy, macroeconomic management, and financial regulation. In particular, capital account regulation emerges as a key instrument to prevent excessive exchange rate appreciation and promote stability, thereby creating the conditions for long-term investments in technology-intensive sectors. The comparison with China's experience shows that only a sustained commitment to technological *upgrading*, combined with managed macroeconomic prices and capital controls, can place Brazil on a path of sustainable growth and global competitiveness. By integrating Brazil's recent industrial trajectory with insights from the New Developmentalism literature, this article contributes to the broader debate on reindustrialization and structural change in emerging economies.

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