Industrial policy for prematurely deindustrialized economies after the Covid-19 pandemic crisis: Integrating economic, social and environmental goals for Brazil*

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Resumo

A desindustrialização não afeta igualmente todos os países. Enquanto nos países desenvolvidos ela é induzida pelo progresso tecnológico, que contribui para o aumento do PIB per capita, na maioria dos países em desenvolvimento a desindustrialização tem acelerado prematuramente e o crescimento econômico tem sido fraco e instável. Entretanto, essa situação não é irreversível. Estudos recentes mostram evidências de inexistência de desindustrialização nos segmentos industriais mais inovativos, seja medindo pelo valor adicionado no PIB ou pela participação do emprego manufatureiro no emprego total. Considerando que o setor manufatureiro ainda é relevante para o desenvolvimento econômico, um dos objetivos prioritários da política industrial é prover e combinar instrumentos diversos visando à reversão da desindustrialização prematura. Em linha com a abordagem do sistema nacional de inovação neoschumpeteriano, concebemos a política industrial de forma sistêmica e efetivada por planos nacionais de desenvolvimento orientados por missões de longo prazo (*mission-oriented*). Utilizamos a matriz insumo-produto da economia brasileira para estimar o impacto sobre o total do emprego, a geração de empregos verdes (*green jobs*) e de empregos tecnológicos (*tech jobs*) decorrente do incremento da demanda final. Com base em argumentos teóricos e evidências empíricas sobre a economia brasileira nas últimas décadas, propomos uma política industrial para o Brasil após a crise pandêmica da Covid-19, identificando missões e integrando prioridades orientadas para i) reindustrialização; ii) geração de empregos; iii) redução da desigualdade social; iii) inserção na economia digital; e iv) substituição gradual das tecnologias de alta por baixa emissão de dióxido de carbono(C02). Embora as recomendações sejam endereçadas ao Brasil, o estudo pode ser útil a diversos países em desenvolvimento que enfrentam desindustrialização prematura e estagnação econômica nas últimas décadas.

Palavras-chave: desindustrialização prematura; desenvolvimento econômico; política industrial; Brasil.

Classificação JEL: O14; O25; O29; O38.

Abstract

Deindustrialization has not equally affected countries. In developed countries, deindustrialization is driven by technological progress, which contributes to increasing GDP per capita, whereas, in most developing countries, deindustrialization has prematurely accelerated and economic growth has been weak and erratic. This situation is not irreversible, though. Recent studies also show that, at a sub-sectoral level, the most innovative manufacturing groups are not deindustrializing in both value-added and employment shares. Since manufacturing still matters, one of the primary roles of industrial policy is to combine instruments to reverse premature deindustrialization. In line with the Neoschumpeterian national innovation system approach, industrial policy is viewed systemically and conceived as long-term mission-oriented national plans. In this paper, we provide several descriptive statistics data and empirical simulations on overall employment and tech and green jobs from an increase in final demand using the input-output methodology. Based on theoretical and empirical analyses, we suggest an industrial policy for Brazil after the Covid-19 pandemic crisis by identifying missions and priorities oriented to (i) reindustrialization; (ii) promoting innovation; (iii) generating formal jobs; (iv) reducing social inequality; (v) engaging in the digital economy; and (vi) gradually replacing high carbon dioxide (CO2) emissions technologies with lower ones. We hope that the policy suggestions are helpful for similar developing countries that have faced premature deindustrialization and stagnation in the last decades.

Keywords: premature deindustrialization; economic development; industrial policy; Brazil.

JEL classification: O14; O25; O29; O38.

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1. Introduction

Since the 1970s, the global economy has changed, being driven by radical technological revolutions, like the information and communication industries revolution and, more recently, the so-called Industry 4.0 (or digital) revolution. Even though these new technologies have increased the role of tradable services in both the productive structure and global trade, it is misleading to expect the world will be transformed into a service economy. As Bianchi and Laboury (2018: 51, boldface ours) point out, this fourth industrial revolution (that is, the digital revolution), driven by robotics, artificial intelligence, big data, the internet of things, biotechnologies, genomics, new material, and renewable energy, is characterized by the "**real integration** [not the separation] of science and production, and **not just interaction** as in the previous industrial revolutions." This means that the role of manufacturing as an engine of growth could be reduced but not eliminated since manufacturing will continue acting as the primary source of generation and diffusion of technical progress (Aiginger and Rodrik, 2020). Moreover, although new technologies are labour-saving, the actual impact of the digital revolution on employment is not so evident in the long run.

What is evident, however, is that deindustrialization has not equally affected countries worldwide. In developed countries, deindustrialization is driven by technological progress and has manifested in the drop of the share of manufacturing employment in total employment. Yet, in most developing countries, deindustrialization has prematurely accelerated. Its explanatory factors vary from the high global competition (especially from China) to an industrial policy that is either inappropriately coordinated or lacking coordination all together with other policy spheres (Rodrik, 2016). For the developing economies that have not suffered from premature deindustrialization, Asian countries provide a good example, where the share of manufacturing value added increased from 13.5% to 19.1% on average between 1970 and 2017. In contrast, in Latin American economies, this share considerably decreased from 18.6% to 13.9% in the same period. Premature deindustrialization measured as the share of manufacturing employment in total employment has also shown a similar behaviour: while this share rose from 11.9% to 14.5% on average in Asian countries in the period 1970-2017, it significantly dropped from 15.5% to 11.9% in Latin America in the same period (Araújo et al., 2021: 2).

Although many developing countries in Latin America and elsewhere suffer from a deep premature deindustrialization, this situation is not irreversible. Tregenna and Andreoni (2020) recognize that this phenomenon represents a threat to the economic development of low and middle per capita income economies because the manufacturing sector still acts as an engine of growth. However, they argue that most empirical studies calculate the degree of premature deindustrialization based on aggregate calculations of the share of manufacturing value added in total GDP or manufacturing employment in overall employment. Since the pace of labour productivity growth and employment creation varies within the manufacturing sector, the authors compare the manufacturing pattern by technology level in 1993 and 2010. They show empirical evidence that high-tech manufacturing sub-sectors are "monotonically increasing their shares of both employment and GDP." This result suggests that "at the increasing level of economic development (measured by GDP per capita), the cross-countries benchmark trajectory is one of continuous industrialization." They also conclude that medium-tech manufacturing sub-sectors show a small but not a dramatic drop in their value-added share; in contrast, their employment share indicates some tendency of stabilization. Dosi, Riccio, and Virgilitto (2021) reach similar results using different methodologies and regressions. They conclude that the most innovative manufacturing groups (basically machine and equipment and science-based manufacturing sub-sectors) are those exhibiting increases in both value-added and employment shares. However, paradoxically, their contribution to employment generation is relatively minor compared to the labour-intensive and scale-intensive manufacturing sub-sectors.

One developing country most severely damaged by premature deindustrialization in the last decades is Brazil. The share of manufacturing value added in total GDP (at 2015 constant price) decreased from 21.1% to 11.9% between 1980 and 2020 (Morceiro, 2021).[1] As to the share of the manufacturing employment in total employment in Brazil, the result has traditionally been disappointing. Nassif et al. (2020) document an almost continuous trend of transferring a significant share of the labour surplus from traditional agriculture to services of low-skilled labour and low productivity (e.g., retail and personal services) throughout the industrialization in Brazil in the period 1950-1980.[2] According to the National Household Sample Survey (PNAD-IBGE/Annual Series), the highest labour share absorbed by the Brazilian manufacturing industry, corresponding to 16.2%, was reached in 1986. In 2018, this share had reduced to only 10.8%.[3]

Such a behaviour contradicts many of the economic development experiences of late-industrializing countries in Asia after World War II. Those countries are marked by the absorption of a large share of labour surplus from the low labour productivity of agriculture,[4] as predicted by the Lewis model (Lewis, 1954). In the Brazilian economy, the reasons for the historically low capacity of the manufacturing industry to create jobs vary from the lack of complete integration of the local markets to high regional and social inequalities (Furtado, 1961; 1992:174-189). Since manufacturing still matters, one of the primary roles of industrial policy is to combine instruments to reverse the premature deindustrialization observed in many developing countries, including Brazil. But in line with the Neoschumpeterian national innovation

[1] These series were carefully calculated at basic prices, by adjusting to the 2010 System of National Accounts methodology by the Brazilian Institute of Geography and Statistics (IBGE in Portuguese), correcting for methodological changes and the financial dummy.
[2] See Nassif et al. (2020), especially Figure 2 on page 7.
[3] This data is provided by the 2020 System of National Accounts (SNA-IBGE), whose methodology is close to the PNAD's.
[4] For empirical evidence, see Amsdem (2001), Palma (2005), Rodrik (2016) and Araújo et al. (2021).

system approach, industrial policy is viewed systemically and conceived as long-term mission-oriented national plans (Mazzucato, 2021). Therefore, it must be connected and harmonized with the other economic and social spheres, such as science and technology, education and training, physical and human infrastructure, and, last but not least, the macroeconomic policies.

Mazzucato (2021) proposes a mission-oriented approach since "partnerships between the public and private sectors solve key societal problems." Despite exemplifying her framework with US achievements in high-tech industries like space missions, the internet and so on, a mission-oriented industrial policy can be widely understood as nothing more than a long-term national development plan with directions, priorities, and instruments to achieve economic and social goals. In Mazzucatto's (2021: 8) words:

"It means choosing directions for the economy and then putting the problems that need solving to get there at the centre of how we design our economic system. It means designing policies that catalyze investment, innovation, and collaboration across a wide variety of actors in the economy, engaging both business and citizens."

Regarding Brazil, although its economy has suffered from stagnation since the 1980s, the Covid-19 pandemic crisis has evidenced the weakness of its labour market, a market characterized by high informality and disguised unemployment, as well as extreme social inequality. In addition, there has also been a growing consensus globally for the need to reduce greenhouse gas emissions. After the pandemic, industrial policy will thus have to deal with four challenges: first, provide mechanisms to reindustrialize the Brazilian economy by absorbing unemployed and informal workers into the formal labour market; second, boost labour productivity by promoting innovation, engaging in the digital revolution and improving education and training; third, reduce the country's extreme social inequality; and fourth, replace high CO2 emitting technologies with low carbon options.

In light of the above, this paper has three goals: (i) analyze reindustrialization as an opportunity to integrate economic, social, and environmental goals in developing countries, with particular reference to Brazil; (ii) provide several descriptive statistics data on Brazil's productive structure and trade patterns, as well as empirical simulations on overall employment and different types of jobs (mainly, tech and green jobs) from an increase in final demand with the input-output methodology; and (iii) based on the theoretical analysis and these empirical results, suggest industrial policy for Brazil as a mission-oriented national plan by identifying the main missions and addressing the main sub-sectoral priorities. We hope that the policy suggestions are helpful for similar developing countries that have faced premature deindustrialization and stagnation in the last decades.

The remainder of this paper is organized as follows. Section 2 briefly discusses why the recovery and diversification of the manufacturing sector still matter for accelerating technical progress and the catching-up trajectory in prematurely deindustrialized economies. This section also analyses how the current digital revolution challenges developing countries' governments to conciliate the promotion of labour-saving manufacturing industries with the necessity of employment recovery. Section 3 presents the case of Brazil by discussing reindustrialization as an opportunity to integrate the economic, social, and environmental agenda after the Covid-19 pandemic crisis. We offer this analysis in two steps: firstly, we identify the set of economic, social, and environmental problems through a brief history and descriptive statistics data; and secondly, we estimate some empirical evidence on the impact of final sub-sectoral demand on the capacity to generate overall employment as well as medium & high-tech skilled jobs and green jobs. Section 4 uses these results to suggest a set of proposals for mission-oriented industrial policy and choose the priorities at the disaggregated sub-sectoral level. Finally, Section 5 draws the main conclusions.

2. What do we know about industrialization, premature deindustrialization, and stagnant economies?

The literature on economic development discusses the role of the manufacturing sector as an engine of growth. However, this particular role is not present in the neoclassical framework, for which all sectors work with technologies subject to constant returns to scale. Moreover, the neoclassical approach implicitly incorporates the hypothesis that all sectors produce goods with the same income elasticity of demand. From the structuralist view, in contrast, at least two empirical observations make the manufacturing industry, differently from the traditional primary and tertiary sectors, act as an engine of growth: (i) it is the primary source of creation and diffusion of technical progress in the economy as a whole; and (ii) as a result of the cumulative effects of technical progress, it is subject to static and dynamic returns to scale (Marx, 1867; Young, 1928, Kaldor, 1966, 1967; Dosi, Pavitt and Soete, 1990).

Based on the historical evolution of capitalism since the Industrial Revolution, in the eighteenth century, the structuralist tradition argues that economic development is marked by the following stylized facts or empirical regularities: (i) The transition of an underdeveloped to a developed economy involves a process of structural change through which labour surpluses are shifted from the sector of lower labour productivity (mainly traditional agriculture) to the higher one (manufacturing) [Lewis, 1954]; (ii) As this latter sector has a high potential to create and spread technical progress throughout the economy, it commands the average growth rates of aggregate labour productivity and long-term economic growth (Kaldor, 1967, Prebisch, 1949, 1951); (iii) As this process is accompanied by an intense urbanization and a growing demand for services (transportation, retail, personal and governmental services, etc.), part of the labour shifting is absorbed by the service sector; (iv) Even when the economy reaches a per capita income level close to the average of the world economy, it continues showing significant labour productivity gaps across sectors, notwithstanding that such gaps tend to decrease over time (Kaldor, 1967); and (v) As the labour surplus is eliminated, the overall labour productivity growth, rather than the structural change mechanism, depends on the capacity of each sector to generate or incorporate technical progress from both manufacturing and high-tech services, such as machines & equipment, robotics, artificial intelligence and so on (McMillan and Rodrik, 2011).

The debate on deindustrialization revolves around whether or not the manufacturing sector loses its capacity to act as an engine of growth when a continuing drop of its value-added share in total GDP or its labour share in overall employment is observed. Indeed, deindustrialization goes back to Kaldor's (1966) investigation on the causes of sluggish economic growth in the United Kingdom through the 1960s.

The debate gained momentum when Rowthorn (1994), based on a sample of 70 countries, interpreted deindustrialization (measured as the share of manufacturing employment in total employment) as a natural phenomenon that followed an inverted U-shaped curve: it initially rises as per capita income increases, then reaches a maximum, and finally drops after the per capita income hits a turning point. Later, Rowthorn and Ramaswamy (1999), based on a sample of 18 industrialized countries for the period 1963-1994, showed that deindustrialization in these countries manifested from a drop in the manufacturing employment share rather than in the value-added share. By accepting that the manufacturing sector still works as an engine of growth, they point out that its higher labour productivity growth provokes a decrease in relative prices of manufacturing goods, sustaining, therefore, the demand stimulus for them. In other words, at least in advanced countries, natural deindustrialization is predominantly understood as a result of technological progress.

In addressing the issue of premature deindustrialization, Palma (2005) and Dasgupta and Singh (2006) showed that deindustrialization does not appear naturally in developing countries. In his seminal paper, Palma (2005),[5] based on a sample of 105 countries in the period 1970-1998, shows empirical evidence that the average per capita income turning point from which countries entered into deindustrialization drastically reduced from US$20,645 to US$8,691 between 1980 and 1998 (at PPP 1985 US dollar). Thus, Palma argues that since the early 1990s many developing countries (especially in Latin America) have prematurely deindustrialized (that is, before reaching a higher per capita income turning point) not because of the impact of technological progress or globalization. Instead, this phenomenon has prematurely occurred because of the rapid liberalizing economic reforms (trade liberalization, financial and credit markets, external capital openness, etc.) that were adopted as "shock therapy" (Lin and Chang, 2014). Moreover, as Palma (2005) points out, most Latin American governments, differently from Asia's, have replaced an agenda prioritizing a development strategy towards the catching up for one concentrated in price stabilization.[6]

By recognizing the role of manufacturing as an engine of growth, Felipe et al. (2019:140), in a paper entitled "Manufacturing matters, but it is the jobs that count," ask the critical question of "how success in industrialization should be measured — is it more important to produce large amounts of manufacturing value added, or to create manufacturing jobs?" They remind us that the mechanisms through which the manufacturing sector boosts and sustains productivity and economic growth over time are activated by both manufacturing value added and employment growth dynamics. However, the authors (op.cit: 141) point out that "in a world of export-led industrialization, manufacturing employment is likely to be a stronger predictor of prosperity than manufacturing output." To test this hypothesis, they provide several regressions for manufacturing value added and employment shares of 63 countries in the period 1970-2010 and show the following conclusions:

"i) All of today's rich non-oil economies enjoyed at least 18% manufacturing employment shares in the past; ii) They often did so before becoming rich; iii) Manufacturing peaks at lower employment shares today (typically below 18%), than in the past (often over 30%); iv) Compared with employment, output shares are weak predictors of prosperity, and are under less pressure; and v) Late developers' manufacturing employment shares peak at much lower per capita incomes than previous studies have shown".

Felipe et al. (2019) does not explain, however, why some developed countries were able to keep the share of the manufacturing value added in total GDP since the 1960s (e.g., the United States),[7] and why several Asian countries increased both manufacturing and employment shares between 1970 and 2017, as already shown. Moreover, a new strand of research that has emerged in the past few years has explored sub-sectoral heterogeneity and different kinds of deindustrialization.

Tregenna and Andreoni (2020) are the first to present empirical evidence on deindustrialization using a manufacturing sub-sectoral analysis from a sample of 67 countries. They show that while the inverted U-shaped curve is evident for low and some medium-tech sub-sectors, high-tech manufacturing is the group that does not follow this behaviour. Instead, this latter group shows a rise in both manufacturing value added and employment shares, suggesting that "the more specialized, sophisticated and high-tech a manufacturing activity, the less concave is its pattern of development, becoming a monotonically increasing line and even a convex curve for very high-tech sub-sectors" (op.cit.: 27). The authors (op.cit: 28) also observe that "this relationship stands even in the case of capital- and robot-intensive

[5] The seminal credit must be awarded to J. G. Palma, who published the quoted reference as a working paper in 2004.

[6] See also Palma (2019).

[7] According to Baily and Bosworth (2014:3), despite the long-standing drop in the US manufacturing employment share, its manufacturing value added share has kept constant in price-adjustment terms since the 1960s. They point out that these trends seem "inconsistent with stories of a recent or sudden crisis in the US manufacturing sector."

sectors such as automotive production, suggesting that premature deindustrialization does not necessarily have to lead to a reduction in employment."

Dosi, Riccio, and Virgilitto (2021) reach similar results using different methodologies and regressions. They show that globalization has accelerated deindustrialization since the early 1990s, while denying that it can be treated as a natural phenomenon driven by income growth and technical progress. In the authors' words (op.cit.: 17):

"First of all, if there were a natural tendency to deindustrialization driven by technical progress, we should have observed a neater anticorrelated pattern between increasing value-added shares and decreasing employment shares. However, this is not what we observe: indeed, the two variables are moving in the same direction in developed and developing countries. Second, some highly innovative sectors, often belonging to the "upstream" aggregate, keep non-reducing or even increasing employment shares as income grows."

Dosi, Riccio, and Virgilitto's paper show sound evidence that there are several varieties of deindustrialization, both on aggregate and sub-sectoral terms. The main contribution of their study is to explore the empirical evidence of deindustrialization at the sub-sectoral level within the Neoschumpeterian and the evolutionary dynamics of innovation and technical progress. As the authors point out, "potato chips" do not have the same dynamic impact of "microchips" on labour productivity and growth dynamics. Therefore, they break down the manufacturing sector into four groups according to Pavitt's (1984) classic taxonomy, which is based on factor and technological content, economies of scale intensity, competitive position on the supply chain, and science and knowledge. These groups are "supplier dominated" (basically natural-resource based and labour-intensive sub-sectors), "scale intensive" (capital intensive industries such as paper, plastics, refined petroleum products, basic metals, and motor vehicles), "specialized suppliers" (machinery and equipment, electrical machinery and other transport equipment), and "science-based" (chemicals, office, and computing machinery, communication equipment, and medical, precision and optical instruments).

By using a broad database for 23 manufacturing industries of 173 countries from 1963 to 2013, Dosi, Riccio and Virgilitto's main findings are as follows:[8] (i) Not all groups show the typical U-shape curve: the tests corroborate canonical U-shape only for supplier dominated and scale intensive groups, while science-based manufacturing figures out as an exception since it shows a rising trend in both value-added and employment shares; (ii) By comparing the tendencies in developed and developing countries, we see that supplier dominated follows a solid trend of deindustrialization, with science-based and specialized suppliers growing both in terms of value-added and employment shares; in the case of scale intensive manufacturing, the results suggest a reallocation of production from developed to developing countries in the last decades as both value-added and employment shares experience a sharp decline in the former, while the value added shows a vigorous increasing trend in the developing world (the employment share does not vary); and (iii) In conclusion, the most innovative manufacturing groups are those revealing increases in both value-added and employment shares, although, paradoxically, their contribution to employment generation is relatively minor in comparison to the supplier dominated and scale intensive ones.

These empirical results have a clear policy implication: the new segments of the service sector associated with the digital economy (robotics, artificial intelligence, big data, the internet of things, etc.) may change but do not rule out the role of the manufacturing sector as an engine of growth. This implication means that manufacturing continues to act as a fuel for low and middle per capita income economies to catch up. Several reasons make us support such a perspective. First, manufacturing is responsible for around two-thirds of total private research and development (R&D) in the world and between 53% and 73% of all patents issued in the most innovative countries, such as the United States, Japan, and Germany (Manyika et al., 2012).[9]

Second, as Galindo-Rueda & Verger (2016) documented, manufacturing sub-sectors possess most of the technological efforts (measured by the ratio of R&D to value added) among OECD countries.

Third, as Bianchi and Labory (2018) argue, the so-called Industry 4.0 tends to actually integrate with manufacturing throughout the twenty-first century rather than merely interact. Therefore, it is more appropriate to understand the manufacturing sector and the medium and high-tech services as an ecosystem of complex technologies that generate dynamic feedback than isolated activities.

And fourth, both poor and developing countries cannot directly jump to medium and high-tech services without establishing a relatively diversified and competitive manufacturing sector. As Amsden (2001) documented, there is no historical experience in which a country achieved high per capita income without industrialization. Therefore, deindustrializing economies will necessarily have to recover their old manufacturing industry as an additional condition to advance in more sophisticated technologies in manufacturing together with the new services. The reindustrialization of the old manufacturing industry must also gradually replace technologies with high carbon dioxide (CO2) emissions for lower ones. This necessity is justified not only for ethical but also for economic reasons, since the international community will rightly press for a greener global economy, which will have implications for countries that want to play and position themselves in the international competitive game.

In the late 1960s, Kaldor (1967: 54) stressed that "there can be little doubt that the kind of economic growth, which involves the use of modern technology and eventuates in high real income per capita, is inconceivable without

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[8] Due to the lack of data for all countries, some results refer to the period 1971-2011.

[9] See also OECD's Analytical Business Enterprise Research and Development database.

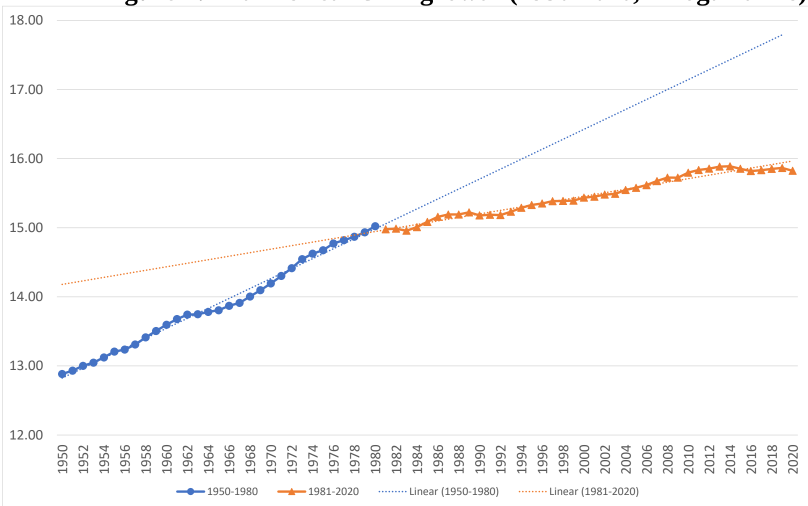
industrialization." Empirical evidence on premature deindustrialization based on sectoral heterogeneity shows that Kaldor's statement continues to be valid even today. We share Aiginger and Rodrik's (2020: 15) theoretical and normative views according to which manufacturing will continue to play its central role in the game of technological change and that "industrial policy is a systemic approach that coordinates innovation, regional policy, and trade policy, with manufacturing at its core while affecting upstream and downstream industries, sectoral change, clusters, and networks."

3. The case of Brazil: main problems and empirical simulations

3.1 Identifying Brazil's main problems

Brazil is a clear case of a country that, after following an initial trajectory of catching up between 1950 and 1980, has entered into premature deindustrialization and falling behind since then (Nassif, 2008; Nassif, Feijó and Araújo, 2015). Figure 1 shows the long-term trend of Brazilian GDP between 1950 and 2020. The much steeper line in the early 1980s marks the beginning of a long period of economic stagnation which has lasted more than four decades.

Figure 1: Brazil's real GDP growth (1950-2020, in logarithms)



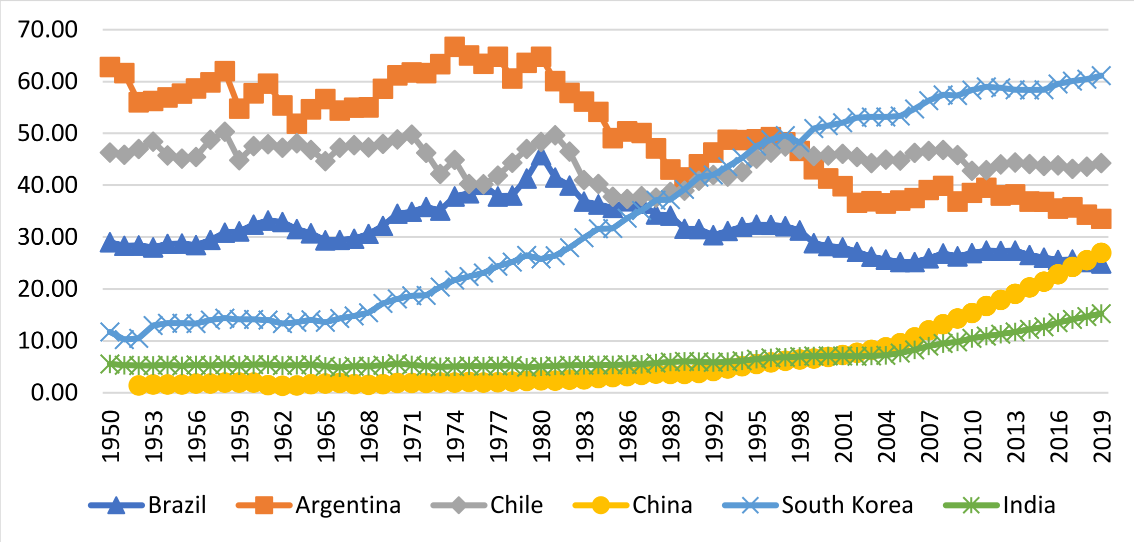
Source: Brazilian Institute of Geography and Statistics (IBGE). Authors' elaboration.

Figures 2 and 3 also depict opposite trajectories of the Brazilian economy in the last seven decades. Labour productivity grew at 4.5% on average between 1950 and 1980, while it showed growth rates near zero in 1981 to 2020 (Figure 2). Figure 3 illustrates the technological gap of selected countries in comparison with the United States. Since Brazil and South Korea engaged in industrial policies for boosting economic development almost simultaneously (Brazil in the early 1950s and South Korea in the early 1960s), it makes more sense to compare both countries' technological trajectories over time. While South Korea has kept an uninterrupted catching-up path since then, Brazil successfully pursued a similar trend only up to 1980. In 2019, the technological gap of the Brazilian economy in relation to the United States was higher (75%) than the one prevailing in 1950 (71%), a clear indicator of Brazil's falling behind. China's economic development from the 1980s on is also an intriguing case to compare with Brazil's. When China established catching up as its central mission, its initial conditions were fairly behind Brazil's. Yet, in 2018, the Chinese relative technological gap was smaller than the Brazilian one.

Figure 2: Average growth rates of aggregate labour productivity in Brazil (1950-2020; in %)

Note: Labour productivity is calculated as the ratio of GDP to total employees.
Sources: Groningen Growth and Development Centre, https://www.rug.nl/ggdc/productivity/, for the period 1950-1980; and *Fundação Getúlio Vargas* (FGV-IBRE), for the period 1981-2020, https://ibre.fgv.br/observatorio-produtividade/artigos/nota-metodologica-dos-indicadores-anuais-de-produtividade-do-0. Accessed on 29 March 2021.

Figure 3: Labour productivity in Brazil and selected countries in comparison with the U.S. (1950-2018; in index numbers; US labour productivity = 100)



Source: *The Conference Board Total Economy Database* (Adjusted version, April 2019), accessed 15 July 2020. Authors' elaboration

Brazil's growth (1950-1980) and stagnation trajectories (1981-2020) involve particularities that can be summarized as follows. First, during the import-substitution strategy (1950-1980), governments designed and implemented ambitious industrial policies (National Plans of Development) by conceding domestic protection against imports and increasing and diversifying exports, especially manufactured goods. This left plenty of problems on both the micro and macroeconomic sides: lack of selectivity, high import tariffs, low government compliance, extreme foreign technological dependence, an increase in social inequality on the microeconomic side, and complacency with high inflation rates and external indebtedness on the macroeconomic side. Despite all these problems, the Brazilian economy experienced high dynamic efficiency, expressed by significant growth of real annual GDP (7.5%) and labour productivity, which was largely offset by a static inefficiency of resource allocation.

In contrast, chronic inflation and external debt crises (1981-1994) and the liberalizing economic reforms from the 1990s on marked the period 1981-2020. After the 1990s, particularly, the Brazilian governments have embarked on the set of radical reforms suggested by the Washington Consensus, such as trade liberalization, privatization, financial deregulation, external capital openness, etc., most of which were adopted as "shock therapy." As a result, between 1981 and 2020, the improvement in static efficiency of the Brazilian economy, expressed by the consumers' access to cheaper imported goods, did not translate into higher dynamic efficiency. Consequently, Brazil experienced sluggish economic growth (GDP growth at 2.0% p.y., lower than the world's at 2.7% p.y.), stagnant labour productivity growth, and premature deindustrialization.

The Covid-19 pandemic crisis evidenced several economic, social and environmental problems that have afflicted Brazil for a long time. Identifying these central problems helps map out a guide for designing a mission-oriented industrial policy to renew the Brazilian trajectory towards catching up and improving the population's well-being. The remainder of this subsection will be used to proceed with this task, which will help us to indicate such primary missions. Then, in the following subsection, empirical simulations of the impact of final sectoral demand on the capacity to generate employment in general, medium & high-tech skills jobs, and green jobs will help us to choose the priorities at a sub-sectoral level.

Figure 4 gives a long-term overview of the rise and fall of industrialization in Brazil in the last century. Figure 4 shows a continuing rise of the share of the manufacturing GDP in the Brazilian economy between 1950 and 1980, followed by a monotonical decline since then. The value-added manufacturing share peaked at 21.4% in 1974 and was only 11.9% of Brazilian GDP in 2020.

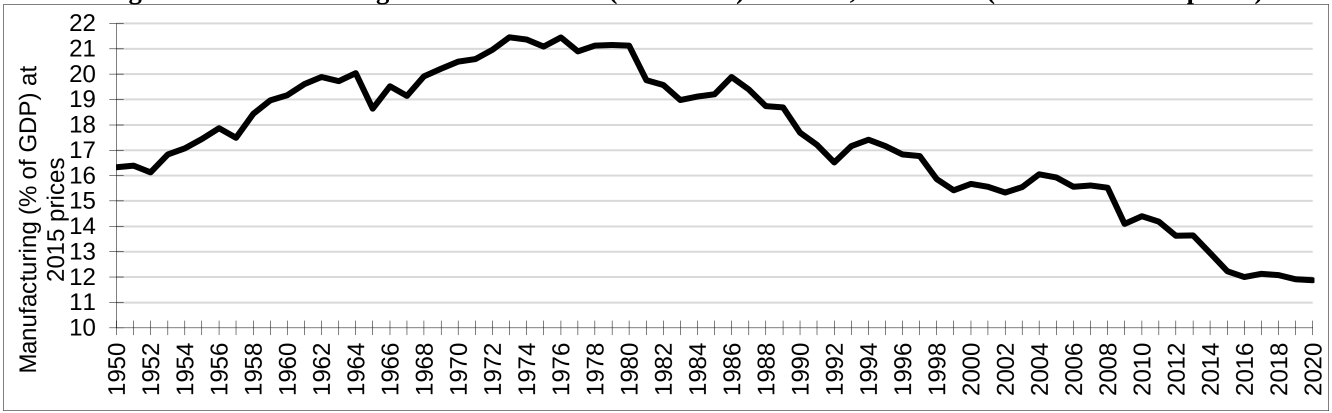
The Brazilian employment database registers that there was an increase in manufacturing employment share in overall jobs until the early 1980s, reflecting the absorption of traditional agricultural labour surplus during the initial industrialization trajectory. Yet, the Brazilian employment share in the manufacturing sector never surpassed the peak of 16.2% in 1986, contrarily to several development experiences (Felipe et al., 2020). The manufacturing employment share fluctuated between 10.5% and 15% throughout 1990 to 2018, confirming that the Brazilian deindustrialization is prematurely manifested much more by the fall in the value-added share than employment share.[10]

Table 1 permits a comparison of Brazil's and selected countries' economic performances between 1981 and 2020 per decade. Except for the 2001–2010-decade, Brazil's GDP grew at lower annual rates than the world's. It is worth noting that Brazil had an underperformance of its manufacturing sector, which grew at lower rates than its GDP in all decades.

[10] The source for the Brazilian employment data is the National Household Sample Survey (PNAD/IBGE).

China and India, in contrast, showed opposite results, suggesting that their manufacturing sector has been one of the engines of growth in both countries in the last decades.

Figure 4: Manufacturing value added share (% of GDP) in Brazil, 1950-2020 (at 2015 constant prices)



Source: Brazilian National Accounts System, Brazilian Institute of Geography and Statistics (IBGE). Authors' calculation and elaboration.

Table 1: Manufacturing and GDP growth per decade (1981-2020; in %)

	The growth rate of GDP (%)				Manufacturing value-added growth rate (%)			
	1981-90	1991-00	2001-10	2011-20	1981-90	1991-00	2001-10	2011-20
Brazil	2.2	2.7	3.9	-0.4	1.3	2.1	2.8	-2.9
China	9.8	10.6	10.8	6.5	n.a.	12.8	12.3	5.7
Germany	2.5	1.6	0.8	0.6	2.0	0.2	1.1	-1.5
India	5.5	6.1	6.9	4.6	7.5	7.0	8.6	4.9
Japan	4.6	1.1	0.7	0.4	4.9	0.5	2.0	0.1
South Korea	10.3	6.7	4.7	2.3	12.6	8.9	6.7	1.8
United States	3.4	3.8	1.8	1.6	2.4	4.9	2.1	0.1
World	3.3	3.2	3.1	2.1	2.9	2.8	5.2	1.9

Note: n.a.: not available. Source: National Accounts Main Aggregates Database from 1981-2019 and Unido for 2020. Authors' elaboration.

Table 2 registers the employment structure in Brazil, considering only the workforce in the formal market.

Table 2: Formal employment share in total employment in Brazil - Selected years from 2010, in %

	2010	2015	2018
Agriculture, forestry, and fishing	12.8	12.3	12.7
Total Industry	53.3	52.3	49.6
Mining and quarrying	76.8	84.0	83.8
Manufacturing	67.4	67.3	65.2
Electricity and gas, water, sewage, waste management activities	65.5	73.2	70.8
Construction	30.5	30.2	24.2
Services	58.0	61.5	58.4
Wholesale and retail trade	50.9	55.7	54.9
Transportation, storage, and courier activities	51.5	55.7	49.1
Information and communication	67.5	76.8	76.3
Financial and insurance activities	90.7	92.9	92.6
Real estate activities	42.7	47.4	54.4
Other service activities	48.2	52.0	47.6
Public administration and defense; public health and education; and compulsory social security	94.0	94.4	94.2
Total Economy	49.9	53.3	50.9

Source: Brazilian National Accounts System from IBGE. Authors' elaboration.

Table 2 reveals the high share of informal workers in Brazil. In 2018, they represented almost half of the overall employment in the Brazilian economy. Data also contrast the very low formality of the labour force in agriculture, forestry, and fishing compared with the other sectors. This result is not surprising since Brazilian agriculture still maintains its dual characteristics of precarious conditions for workers in the Northeast region and better well-being in the modern Southeast, South, and Midwest. Based on the 2017 Brazil Agriculture Census, Souza, Gomes, and Alves (2020: 39) estimate that the income inequality in Brazilian agriculture is one of the highest in the world. The Gini index (closer to 1 means higher income concentration) at the firm level jumped from 0.85 to 0.90 between 2006 and 2017. The workforce's higher formalization occurs in the medium and higher-skilled labour services, especially in the public sector and financial activities. Except for construction, the other segments of the Brazilian industry (including manufacturing) also have a high degree of labour formalization.

The agricultural income concentration impacts both high overall social inequality and regional imbalance in Brazil, whose roots have historical, economic, and political causes that are out of the scope of our study.[11] Even so, it is still worth registering some inequality indicators in Brazil. First, the Gini index related to aggregate income reveals that accelerated economic growth between 1950 and 1980 is not safe against income concentration. The Gini index was still extremely high in 1981 (0.579), peaked in 1989 (0.633), and due to government social transfers and real increases of the minimum wage in the second half of the 2000s, fell to 0.519 in 2015. Then, with the 2015-2016 recession and low growth afterward, it rose again to 0.534 in 2019.[12]

Second, despite still being high, both the poverty and the extreme poverty ratios considerably decreased in Brazil, especially after the 2000s, due to several governmental social programs of income transfers to poor people. The share of the population living with less than 5.50 US dollars a day dropped from 41.1% to 19.6% between 2001 and 2019 (the world, from 65.2% to 43.5%), and those living with less than 1.90 US dollars a day reduced from 11.5% to 4.6% in the same period (from 26.9% to 9.3% in the world).[13] [14]

Third, income disparity also appears between Brazil's geographic regions. Despite concentrating 35.9% of Brazil's population in 2018, the North and Northeast regions had an average per capita income of around 9,174 PPP US dollars, much lower than the country's per capita income of 15,513 PPP US dollars. In particular, the Northeast, considered the poorest region in the country and responsible for 27.2% of the total population, had a per capita income corresponding to 53.2% of the country's per capita income and only 40.8% of the Midwest's per capita income, Brazil's wealthiest region.

The stagnant labour productivity growth and the sluggish economic growth in Brazil in the last decades are explained, at least partially by premature deindustrialization and a macroeconomic regime relatively unfriendly to capital accumulation and technical progress. Nassif, Feijo, and Araújo (2020) stress that the Brazilian macroeconomic regime is more biased towards price stabilization than other long-term goals, especially stimulus ones to boost potential output through capital accumulation and innovation. The authors (op.cit.: 749) show empirical evidence that, in the face of significant capital movements, orthodox inflation targeting regime and a procyclical fiscal policy have been "perpetuating trends of high real interest rates, domestic currency overvaluation and low economic growth in Brazil in the last two decades."

Nassif, Bresser-Pereira, and Feijo (2018) also point out that, in the absence of harmonization between the industrial policy and the macroeconomic regime, the former cannot boost productivity and structural change. In the authors' (op.cit.: 14) words:

"The main role of a consistent macroeconomic regime is, thus, to widen the policy space for seeding good results from the industrial policy. [Moreover], consistent macroeconomic policies create an environment favourable to capital accumulation, innovation, and structural change oriented to economic development and catching up."

In Brazil, for instance, the inability of the three industrial policy programs adopted between 2004 and 2014 to boost investment, innovation, and reverse premature deindustrialization is explained, in part, by the high real interest rates and overvaluation of the Brazilian currency prevailing in most of the period.[15] The reason is apparent: as the former raises capital costs and the latter reduces the expected profit rate, they negatively affect investment and innovation. Nassif, Feijo, and Araújo (2020: 760-761) calculate that between 2006 and 2011, not only was the Brazilian real overvalued (except during transitory short periods), but also the real interest rate was around 6.5% p.y, on average (against 10.5% between 1999 and 2005). It is not surprising that such an economic environment reflects in regressive trade specialization, that is, an export basket with a high share of commodities and imports concentrated in goods of high income-elasticity of demand, as evidenced in empirical studies (Nassif, Feijo, and Araújo, 2015, Nassif and Castilho, 2020).[16] Tables 3 and 4, which use a taxonomy adapted from Pavitt's (1984) to decompose the groups in the manufacturing sector, confirm such a trend.

Table 3 shows the changes in the Brazilian export composition. It registers the rapid augmentation of the primary product share and the significant drop in manufactured goods in total exports between 1990 and 2020. In this period, Brazil developed its extreme dependency on commodity exports (represented by the sum of primary goods and resource-based manufactured goods), which reached 65.8% of total exports in 2020 (against 38.8% in 1990). In addition, there was a fall in the shares of all manufacturing groups, particularly in labour-intensive and scale-intensive goods. Table 4 presents the changes in the Brazilian import composition. It confirms Brazil's extreme dependency as a manufactured goods importer

[11] The best interpreter of these roots is the Brazilian economist Celso Furtado (1961; 1959; 1992).

[12] Data calculated by the authors, based on the World Bank estimate.

[13] The last indicators for the World are related to the 2017 data.

[14] Data calculated at 2011 PPP US dollar by the authors, based on the World Bank estimate.

[15] These industrial policies, whose details can be found on the website of Brazil's Ministry of Development, Industry and Commerce (https://www.mdic.gov.br), were entitled Foreign Trade, Technological and Industrial Policy (*Política Industrial, Tecnológica e de Comércio Exterior*, 2004–2008), Policy for Productive Development (*Política de Desenvolvimento Produtivo*, 2008–2010) and Major Brazil Plan (*Plano Brasil Maior*, 2011–2014).

[16] Coutinho (1997) first coined the term regressive specialization when analysing the Brazilian economy throughout the 1990s. Nassif and Castilho (2020: 672) define regressive specialization as a process "in which both production and export structures are strongly oriented to activities or segments of low technological sophistication and, therefore, to low-income elasticity of demand."

and the country's almost self-sufficiency as a producer of primary goods. Between 1990 and 2020, the share of manufactured goods in total imports increased from 69.1% to 91.8%. Except for the resource-based group, the import shares of all the other groups have grown, especially the more technologically sophisticated ones (scale intensive, specialized suppliers, and science-based).

Table 3: Sectoral share of goods' total exports in Brazil - Selected years from 1990-2020, in %

	1990	1995	2000	2005	2010	2015	2020
Primary Goods (Agriculture and Mining)	17.6	13.9	14.5	18.6	34.4	33.8	45.1
Manufacturing	81.1	84.7	83.4	79.4	63.4	64.3	54.6
Resource-based	21.2	24.0	18.4	21.0	21.2	20.9	20.7
Labour-intensive	10.3	10.0	9.1	6.7	4.4	4.5	2.5
Scale Intensive	32.0	31.5	29.8	29.8	21.1	20.9	19.4
Specialized Suppliers	8.8	9.8	14.0	11.6	8.5	9.9	5.5
Science Based	8.9	9.4	12.0	10.4	8.3	8.0	6.4
Not classified	1.3	1.4	2.1	2.0	2.2	1.9	0.3
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: OECD. Authors' elaboration.

Table 4: Sectoral share of goods' total imports in Brazil - Selected years from 1990-2020, in %

	1990	1995	2000	2005	2010	2015	2020
Primary Goods (Agriculture and Mining)	30.3	11.8	11.8	17.0	12.1	11.8	7.0
Manufacturing	69.1	87.4	87.8	82.7	87.6	87.9	91.8
Resource-based	7.4	8.3	3.8	2.8	3.1	3.6	4.2
Labour-intensive	4.2	6.4	4.4	4.4	5.7	7.1	6.3
Scale Intensive	12.7	25.9	24.1	20.7	28.0	23.3	20.6
Specialized Suppliers	17.4	17.4	19.0	17.6	19.3	19.7	21.0
Science Based	27.4	29.4	36.4	37.0	31.5	34.2	39.7
Not classified	0.6	0.7	0.5	0.3	0.3	0.3	1.2
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: OECD. Authors' elaboration.

Despite Brazil's significant total trade surpluses in the last decade, the high volatility of international commodity prices does not save the country from the long-term balance of payments constraints. Moreover, Brazil's high dependency on commodities is not safe, for the eventual transitory gains obtained by commodity-price booms – the "commodity lottery," using Diaz-Alejandro's (1984) term – do not translate into permanent gains.[17]

The theoretical discussion of Section 2 and the empirical evidence of this subsection draw four primary missions for an industrial policy that could potentially put the Brazilian economy towards a trajectory of catching up: first, reindustrialization and industrial revitalization; second, innovation promotion, technical progress, and creation of dynamic comparative advantages; third, fostering employment, job formalization, and the reduction of social and regional inequalities; and fourth, boosting investment in infrastructure. In addition, given the current digital revolution and the world transition to a greener economy, it is necessary to add two other missions to these primary missions: integrating Brazilian activities into digital technologies and gradually replacing technologies with high carbon dioxide (CO_2) emissions for lower ones.

After the remainder of the empirical section, Section 4 will analyse the motivations and priorities related to these mission-oriented industrial policies. It is worth anticipating that gradually transforming the Brazilian economy into a green economy is both an ethical issue and an economic one. As to this latter issue, there is a definite global trend to make the economy green and sustainable, with important implications for international manufacturing competitiveness through trade agreements and pressure from societies for carbon-neutral production processes and more efficient green products. Moreover, as we shall argue in Section 4, adopting green technologies can open enormous windows of potential opportunities for Brazil when most countries in the world economy will (or will have to) do the same. Whatever these

[17] Several empirical studies confirm the "secular" deterioration of the long-term terms of trade for periphery countries that were exporters of primary goods, such as Coatsworth and Williamson (2002) for the period 1870-1940, the IMF (1994) for the period 1945-1970, and Silva, Prado and Torracca (2016) for the period 1977-2011.

opportunities are, one of Brazil's priority challenges is to improve land use and fight against and reduce deforestation, which was responsible for 44% of the carbon dioxide emissions in 2018 (SEEG, 2019: 4).[18]

3.2 Empirical simulations on employment: overall, tech and green jobs

As anticipated, employment generation, transition to a greener economy, and innovation promotion and technical progress are essential missions for all economies, especially those prematurely deindustrialized like Brazil. This subsection simulates the sub-sectoral impact on overall employment, green jobs, and technological jobs (the latter two defined ahead) from an increase in final demand. Our objective is to identify sub-sectors with a greater intensity to generate these three categories of employment from a demand stimulus to simultaneously match those mentioned missions and support the industrial policy proposals of Section 4.2.

3.2.1 Data and methodological procedures

To perform the simulations, we combined information from two databases. The first is the 2018 input-output matrix for Brazil available at The University of Sao Paulo Regional and Urban Economics Lab[19] (Guilhoto & Sesso Filho, 2005, 2010). This matrix is the most current version disaggregated into 68 sub-sectors (or industries). The second database is the Annual Social Security Information Report (RAIS) – compiled by the Ministry of Labour and Social Security – which contains firms' administrative records, including the number of workers employed in 2,555 occupations in 581 industrial classes. This database provides information on 50 million workers in the formal labour market across the nation. Finally, we use an IBGE crosswalk table to convert the 581 industrial classes into 68 sub-sectors.

Traditionally, science, technology, engineering, and mathematics professionals (STEM) serve as a proxy for technological development. The specific technical occupations are provided by the Brazilian Government Institute of Applied Economic Research (IPEA). Using the Brazilian Innovation Survey's firm-level data, IPEA found that 161 technical-scientific occupations correlate with around 90% of R&D business enterprise expenditures and more than 75% of expenses on innovative activity for Brazil (Araújo, Cavalcante & Alvez, 2009). The occupations encompass engineers, chemists, physicists, researchers, R&D directors and managers, biotechnologists, biologists, mathematicians, and I.T. professionals. We used these 161 occupations as a proxy for technological occupations in the simulations.

The green occupations, on the other hand, were identified by a comprehensive project entitled "Greening of the World of Work", which was prepared for the U.S. Department of Labour Employment and Training Administration and led by researchers at North Carolina State University and the U.S. National Centre for Occupational Information Network (O*NET) Development (Dierdorff et al., 2009; Dierdorff et al., 2011). As Dierdorff et al. (2009:3) point out, "the green economy encompasses the economic activity related to reducing the use of fossil fuels, decreasing pollution and greenhouse gas emissions, increasing the efficiency of energy usage, recycling materials, and developing and adopting renewable sources of energy". We use all the green[20] occupations identified as "green increased demand occupations" since they are existing occupations that will increase with the growth of green economy activities and technologies. We created a crosswalk between green occupations in the US classification and green occupations in the Brazilian classification.

It is essential to mention that such occupations refer to the green economy at a broad level. In addition to decreasing greenhouse gases, they encompass professionals related to research, development and production of "green" materials and machines and equipment for all of the economy's sectors, such as renewable energy (e.g., solar panels) and construction (e.g., green building materials and green retrofitting). Thus, the manufacturing sector will play a key role in developing, producing, installing, and maintaining such materials, machinery and equipment, and adopting fewer polluting technologies.

The total employment by sub-sector was obtained from the input-output matrix. For the impact simulation, we have vectors of total employment, technological occupations (henceforth tech jobs) and green occupations (henceforth green jobs). We follow Guilhoto (2021) for the inter-sub-sector impact simulations with input-output. The Leontief model separates production technology (matrix of technical coefficients, A) from final demand. In the model, sub-sectors (or industries) are represented by a production vector x and a final demand vector y:

$$x = Ax + y \tag{1}$$

Where A represents the matrix of domestic inter-sub-sectoral coefficients. By multiplying A by x we have the intermediate inputs necessary for production. Since the inverse of the matrix $(1 - \mathrm{A})$ exists, we can obtain in matrix notation:

$$\mathrm{x} = (\mathrm{I} - \mathrm{A})^{-1}\mathrm{y} \tag{2}$$

$$\mathrm{B} = (\mathrm{I} - \mathrm{A})^{-1} \tag{3}$$

Where B is the Leontief inverse matrix of total (direct and indirect) requirements; the individual elements b_{ij} show the total output of sub-sector i that is necessary to produce one additional unit of final demand by sub-sector j.

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[18] According to this Report (op.cit.: 4), the other shares related to direct emissions are as follows: agriculture and meat industry (25%); energy (23%); and other industries (8%).

[19] http://www.usp.br/nereus/?fontes=dados-matrizes (Accessed on 15 September 2021).

[20] https://www.onetcenter.org/dictionary/22.0/excel/green_occupations.html (Accessed on 1 September 2021).

Using the traditional Leontief model defined in equations (1-3), it is possible to measure how much total employment as well as tech and green jobs are embodied in final demand (y). For example, when we divide the green jobs of a sub-sector i, c_i, by the sub-sector total output i, x_i, the result shows the intensity of green jobs of sub-sector i, v_i, that is, green jobs generated by one monetary unit of production:

$$v_i = \frac{c_i}{x_i}\, i = 1, 2, \dots, n \tag{4}$$

In matrix notation, (4) can be written as (5), being that the "hat" over a vector denotes a diagonal matrix with the elements of the vector along the main diagonal:

$$\mathrm{v} = \mathrm{c}(\hat{\mathrm{x}})^{-1} \tag{5}$$

Where:
c_i is the green job (or tech job or total employment) of sector i and c is the respective $1xn$ vector.
v_i is the intensity of green job (or intensity of tech job or total employment) of sector i and v is the respective $1xn$ vector.
Combining equations (2) and (5) leads to:

$$\mathrm{c} = \hat{\mathrm{v}}(\mathrm{I} - \mathrm{A})^{-1}\mathrm{y} \tag{6a}$$

$$\mathrm{G} = \hat{\mathrm{v}}(\mathrm{I} - \mathrm{A})^{-1} \qquad \text{6b)}$$

Where the total green jobs (or tech jobs or employment) can be associated with the final demand. Like matrix B in equation (3), matrix G in (6b) shows for each sub-sector how much directly and indirectly green jobs (or tech jobs or employment) are generated for each monetary unit produced for final demand.

3.2.2 Simulation results

Table 5 shows the simulation of the impact of a final demand increase of US$10 million in each sub-sector on the direct and indirect generation of jobs, green jobs, and tech jobs. Direct generation refers to employment created in the sub-sector that received the increase in demand, and indirect generation refers to employment created in the production chain of this sub-sector. The last two columns of the Table display the intensity of the impact on green jobs and tech jobs, that is, the green jobs (or tech jobs) generated divided by the total employment generated by the increase in final demand. For the average of the whole economy (last line of the Table), an increase of US$10 million in the sub-sector final demand generates 538.29 total employment, 23.18 green jobs that represent 4.31% of total employment, and 3.99 tech jobs representing 0.74% of total employment. Cells highlighted in yellow display the sub-sectors that have a higher impact than the average economy.

Thus, the greater the intensity of the impact on tech jobs (or green), the greater the percentage of tech jobs (or green) in total employment generated for each US$10 million increase in final demand. The sub-sectors of science-based groups, specialized suppliers, and high-skilled services have the greatest intensity of impact on tech jobs. Some scale-intensive sub-sectors – such as motor vehicles and parts and accessories for motor vehicles – also had an above-average impact intensity. These manufacturing sub-sectors have high technological opportunities and usually spend a higher share of the value added on R&D, information services (mainly software), and engineering and R&D services (Breschi & Malerba, 1997; Galindo-Rueda & Verger, 2016).

It is noteworthy that the Brazilian State has important public research institutes that carry out R&D in various sub-sectors; for example, the Department of Aerospace Science and Technology (DCTA acronym in Portuguese), Brazilian Space Agency (AEB acronym in Portuguese) and the Navy Technological Centre of Sao Paulo (CTMSP acronym in Portuguese) have all contributed to other transport equipment, thus obtaining the largest impact in tech jobs in manufacturing. The government acts through sub-sectoral regulations to increase investments in R&D with the Computers Law[21] (*Lei de Informatica* in Portuguese) and with the research institute Centre of Excellence in Advanced Electronic Technology (CEITEC acronym in Portuguese) in the sub-sector of computer, electronic and optical products.

Other sub-sectors regulated by the government, such as education and health, energy and oil extraction, and mining, have an intensity of impact on tech jobs above the average for the economy (Table 9). In these sub-sectors, the Brazilian State acts directly via public research institutes and indirectly via sub-sector regulation to increase technological effort (Morceiro, 2018). For example, in public health, there are several public research institutes – such as the Oswaldo Cruz Foundation (Fiocruz[22] acronym in Portuguese), Butantan, Vital Brazil, Adolfo Lutz, and Pasteur – that work in areas related to population health and tropical diseases, including conditions such as AIDS, Chagas, tuberculosis, schistosomiasis, malaria, leprosy, measles, rubella, meningitis, hepatitis as well as with vaccines, serums and pathogens of great social interest. Fiocruz and the Butantan Institute have produced 76.8% of the 227 million Covid-19 vaccines[23] applied in Brazil. In mining and quarrying, the State determines that oil and natural gas extraction companies invest 1.0% of gross revenue in R&D activities; the public research institutes Company for Research of Mineral Resources (CPRM acronym in Portuguese) and Centre for Mineral Technology (CETEM acronym in Portuguese) play a prominent role with R&D investments over US$100 million in mining. Finally, in energy, the research conducted by the National Nuclear

[21] Regulation that grants tax benefits and requires in return the investment of 5% of revenue in R&D.
[22] Fiocruz is one of the three institutions that invests the most in R&D in Brazil along with Petrobras and Embrapa (Morceiro, 2018).
[23] By 23 September 2021, about 70% of the Brazilian population received at least one dose, and 40% were fully immunized with two doses or a single dose (Source: https://qsprod.saude.gov.br/extensions/DEMAS_C19Vacina/DEMAS_C19Vacina.html).

Energy Commission (Cnem acronym in Portuguese) – an agency of the Brazilian government – total around US$100 million and, through regulation, the State determines that energy generation and distribution companies allocate to R&D between 0.2% and 0.4% of net revenue (Morceiro, 2018). In education, many universities and public institutes carry out R&D like the Technological Institute of Aeronautics (ITA acronym in Portuguese) linked to aerospace research conducted by Embraer. In short, directly and indirectly, the State stimulates research, being directly responsible for at least half of the spending on R&D in Brazil (Morceiro, 2018).

Table 5: Direct and indirect impact of an increase of US$10 million on the Brazilian subsectors' final demand

	Green Jobs	Tech Jobs	Total Employment	(I) / (III)	(II) / (III)
	(I)	(II)	(III)	In percentage	
Primary Goods (Agriculture and Mining) (Average)	**10.27**	**2.25**	**612.2**	**1.68**	**0.37**
Agriculture, forestry and fishing	**10.36**	**1.27**	**1,106.4**	**0.94**	**0.11**
Agriculture, including support activities	8.73	1.43	743.8	1.17	0.19
Livestock, including support activities	11.65	1.28	1,678.8	0.69	0.08
Forestry and logging, including fishing and aquaculture	10.70	1.10	896.7	1.19	0.12
Mining and quarrying (Average)	**10.20**	**2.98**	**241.6**	**4.22**	**1.23**
Mining of coal and lignite; other mining and quarrying	10.32	3.11	390.0	2.65	0.80
Extraction of crude petroleum and natural gas, and mining support service activities	7.51	2.50	152.7	4.92	1.64
Mining of iron ores	10.74	2.17	183.2	5.86	1.19
Mining of non-ferrous metal ores	12.22	4.14	240.5	5.08	1.72
Manufacturing (Average)	**39.47**	**2.95**	**441.9**	**8.93**	**0.67**
Resource-based (Average)	**35.73**	**2.26**	**604.1**	**5.91**	**0.37**
Processing and preserving of meat and fish, crustaceans and molluscs; and dairy products	37.35	2.00	863.0	4.33	0.23
Manufacture of sugar	24.75	2.33	625.8	3.96	0.37
Other food products n.e.c.	32.25	2.30	572.9	5.63	0.40
Beverages	35.31	2.51	376.3	9.38	0.67
Tobacco products	11.57	2.45	474.9	2.44	0.52
Wood products, except furniture	73.13	1.98	711.5	10.28	0.28
Labour-intensive (Average)	**52.38**	**2.44**	**622.2**	**8.42**	**0.39**
Textiles	45.63	2.20	741.6	6.15	0.30
Wearing apparel	34.10	1.83	1,225.0	2.78	0.15
Leather products and footwear	58.11	2.04	685.3	8.48	0.30
Fabricated metal products, except machinery and	80.75	2.97	443.2	18.22	0.67
Furniture and other manufacturing	66.92	2.31	584.9	11.44	0.40
Repair and installation of machinery and equipment	47.49	2.89	420.5	11.29	0.69
Scale Intensive (Average)	**37.62**	**2.98**	**351.3**	**10.71**	**0.85**
Paper and paper products	29.17	2.62	303.7	9.61	0.86
Printing and reproduction of recorded media	38.00	2.82	480.9	7.90	0.59
Coke and refined petroleum products	6.91	2.03	169.3	4.08	1.20
Alcohol (biofuel)	22.94	2.15	529.2	4.33	0.41
Rubber and plastics products	68.06	2.87	336.6	20.22	0.85
Other non-metallic mineral products	44.15	2.90	478.4	9.23	0.61
Basic iron and steel	22.58	2.71	236.5	9.55	1.15
Basic precious and other non-ferrous metals; casting of metals	33.63	2.86	255.3	13.17	1.12
Motor vehicles and bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	36.78	4.19	309.2	11.89	1.36
Parts and accessories for motor vehicles	69.96	4.52	317.7	22.02	1.42
Specialized Suppliers (Average)	**48.12**	**4.87**	**284.8**	**16.90**	**1.71**
Electrical equipment	51.92	3.82	299.1	17.36	1.28
Machinery and equipment n.e.c.	62.61	4.78	338.4	18.50	1.41
Other transport equipment	29.84	6.02	216.8	13.76	2.78
Science Based (Average)	**24.05**	**3.27**	**252.4**	**9.53**	**1.30**
Basic chemicals, fertilizers and nitrogen compounds, plastics and	15.81	2.31	182.8	8.65	1.27
Pesticides and other agrochemical products; paints, varnishes and similar coatings, printing ink and mastics; other chemical products n.e.c.	23.67	3.39	239.1	9.90	1.42
Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	39.98	3.16	359.4	11.12	0.88
Pharmaceuticals, medicinal chemical and botanical products	15.58	3.32	241.4	6.45	1.37
Computer, electronic and optical products	25.25	4.17	239.3	10.55	1.74

Table 5 (Cont.): Direct and indirect impact of an increase of US$10 million on the Brazilian subsectors' final demand

	Green Jobs	Tech Jobs	Total Employment	(I) / (III)	(II) / (III)
	(I)	(II)	(III)	In percentage	
Construction and Energy Infrastructure (Average)	**28.97**	**3.89**	**421.6**	**6.87**	**0.92**
Electricity, gas, steam and air conditioning supply	11.47	3.24	137.0	8.37	2.36
Water supply; sewerage, waste management and	9.37	4.73	384.6	2.44	1.23
Construction	66.05	3.69	743.3	8.89	0.50
Services (Average)	**8.33**	**5.54**	**635.6**	**1.31**	**0.87**
Low and medium-skilled services (Average)	**10.11**	**2.34**	**829.9**	**1.22**	**0.28**
Wholesale and retail trade and repair of motor vehicles and motorcycles	10.88	1.80	761.9	1.43	0.24
Wholesale and retail trade, except for motor vehicles and motorcycles	5.63	2.69	673.7	0.84	0.40
Land transport and transport via pipelines	48.40	1.90	561.8	8.62	0.34
Water transport	11.46	2.59	234.8	4.88	1.10
Air transport	7.07	2.47	226.6	3.12	1.09
Warehousing and support activities for transportation; postal and courier activities	20.53	3.49	376.8	5.45	0.93
Accommodation	6.43	1.98	773.2	0.83	0.26
Food and beverage service activities	10.29	1.19	985.4	1.04	0.12
Real estate activities	0.86	0.35	48.5	1.78	0.73
Administrative and support service activities; except rental and leasing, and security and investigation act.	6.13	5.94	703.9	0.87	0.84
Security and investigation activities	1.89	1.50	728.2	0.26	0.21
Arts, entertainment and recreation	6.12	2.34	1,157.5	0.53	0.20
Other service activities	5.79	4.45	1,165.1	0.50	0.38
Activities of households as employers of domestic personnel	0.00	0.00	3,221.5	0.00	0.00
High-skilled services (Average)	**6.54**	**8.75**	**441.2**	**1.48**	**1.98**
Publishing activities, except software publishing	8.12	4.99	472.8	1.72	1.06
Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	4.83	4.71	397.8	1.21	1.18
Telecommunications	4.85	6.97	286.8	1.69	2.43
Computer programming, consultancy and related activities; software publishing; and information service activities	3.09	35.40	281.3	1.10	12.58
Financial and insurance activities	1.86	3.91	177.8	1.05	2.20
Legal and accounting activities; activities of head offices; management consultancy activities	4.69	3.02	420.9	1.11	0.72
Architectural and engineering activities; technical testing and analysis; scientific R&D	23.05	20.72	498.0	4.63	4.16
Advertising and market research; other professional, scientific and technical activities; veterinary activities	8.59	7.49	447.6	1.92	1.67
Rental and leasing activities	5.34	3.39	350.7	1.52	0.97
Public administration and defence; compulsory social security	3.93	2.82	316.2	1.24	0.89
Public education	3.99	10.97	515.6	0.77	2.13
Private education	2.90	4.45	831.5	0.35	0.53
Human health and social work activities (public)	9.63	9.34	565.1	1.70	1.65
Human health and social work activities (private)	6.77	4.33	614.3	1.10	0.71
Total Economy (Average)	**23.18**	**3.99**	**538.3**	**4.31**	**0.74**

Note: 2018 Data. Sub-sectors highlighted in yellow have a higher impact than the economy average. Source: Authors' elaboration.

As for green jobs, most of the manufacturing, construction, energy, transport services sub-sectors, and engineering and R&D services have had green job generation and impact intensity above the economy average (Table 5). As mentioned in Subsection 3.2.1, the manufacturing sector will play a key role in designing, producing, installing, and maintaining the "green" materials and machinery and equipment required by all economy subsectors, as well as improving efficiency in energy use. Boosting energy efficiency increasingly involves occupations related to production digitization to obtain real-time information for faster decision-making, in addition to typical energy-saving occupations, such as stationary engineers, boiler operators, and boilermakers present in many manufacturing sub-sectors. Specialized professionals will also have to handle and dispose of hazardous waste in the environment in virtually all manufacturing sub-sectors. As it produces numerous types of "green" machinery and equipment, the specialized supplier's group had the greatest impact intensity on green jobs. In transportation, green jobs "cover activities related to increasing efficiency and/or reducing environmental impact of various modes of transportation including trucking, mass transit, freight rail;" and in construction they are related to "new green buildings, retrofitting residential and commercial buildings, and installing other green construction technology" (Dierdorff et al., 2009).

In general, labour-intensive sub-sectors typically have an employment impact above the economy average, such as agriculture, low-skilled services, construction, labour-intensive manufacturing sub-sectors, some resource-based manufacturing sub-sectors, inclusive education, and high-skilled health services (Table 5). Except for education and health, most of these sub-sectors have a high degree of labour informality in Brazil – especially agriculture, construction, and low-skilled services – and the wage per worker is lower than the economy average. However, labour-intensive sub-sectors are essential for the recovery of post-pandemic employment due to the high unemployment rate of 11.1%, according to the IBGE's National Household Sample Survey of February/2022, and the high informality of the Brazilian workforce.

By combining the impact intensity of tech and green jobs, we see that the more sophisticated manufacturing sub-sectors (scale-intensive, specialized suppliers, and science-based) and engineering and R&D services have better performance than the economy average.

4. A mission-oriented industrial policy proposal for Brazil

This section aims to identify the general guidelines of an industrial policy to tackle structural bottlenecks and significant obstacles to socioeconomic development in Brazil. Despite being advanced in relation to most developing countries, it is still incomplete when compared to developed countries. In other words, the objective is not to design policies with associated instruments but to draw a generic roadmap with priorities to build consensus – note that the missions use existing industrial policy instruments, but in a combined way with the specific purpose to increase the success rate of the policy. To fulfil our objective, we base our mission-oriented innovation policies framework on Mazzucato's (2018; 2021) and Kattel & Mazzucato's (2018). However, the mission-oriented industrial policies we propose are broader and do not focus only on innovation.

For Brazil to achieve successful results with the missions, the business environment needs to improve significantly to enable innovation and international competitiveness. A tax reform that eliminates regressive tax and reduces the complexity of indirect taxes is vital – a topic that forms a consensus in the country. Establishing a trade policy more consistent with import tariffs at a moderate level so that firms can learn and develop imitative and innovative capabilities also forms a consensus (Viotti, 2002). Thus, any trade liberalization, if adopted, should not be introduced using linear import tariff cuts (across-the-board), but, rather, as a case-by-case policy instrument ("concertina") for accelerating innovators' learning curve and avoiding excessive imports of close substitute goods. In addition, it is essential to adjust the macroeconomic regime (monetary, fiscal and exchange rate policies) to stimulate domestic production, in line with Nassif, Bresser-Pereira and Feijo's (2018) proposals.

Subsection 4.1, which follows, presents the priority missions to be pursued in the coming decades, and Subsection 4.2 connects industrial policy to these missions.

4.1 Wide-ranging priority missions

The theoretical discussion in Section 2 and the historical and empirical diagnoses of the Brazilian economy presented in Subsection 3.1 are the basis on which we justify and indicate six priority missions to be pursued in the long term, summarized in Table 6.

The main challenges and obstacles to Brazil's development are included in many of the 17 goals of the United Nations Sustainable Development Goals (SDGs)[24], as described in the second column of Table 6. For Brazil to restore and sustain its development trajectory as well as surpass its middle-income level, it is necessary to boost reindustrialization (Mission 1). This means not only increasing the value-added share of the manufacturing sector but also taking advantage of opportunities to update its technological structure, including the gradual substitution of low carbon dioxide technologies for high ones (Mission 6). It is important to stress that Mission 1 can also be addressed to other developing countries suffering from premature deindustrialization.

At the same time, there is a need to innovate more (Mission 2), create formal and good jobs, and reduce social and regional inequalities (Mission 3), advance in the digital economy (Mission 5) and take actions to have a more carbon neutral and sustainable production activity (Mission 6). Additionally, a significant expansion and revitalization of infrastructure (Mission 4) is also required. The motivation for choosing infrastructure as a mission is because Brazil has severe deficiencies in areas such as sanitation, access to treated water, mass transportation in populous cities, and information and communication networks – vital for advancing digitalization (Mission 5) –, not to mention deep spatial inequality in the coverage of physical (roads, railways, electricity), social (sanitation, water, urban mobility) and technological (internet and telecommunication) infrastructure. It is challenging to start an industry in regions with inadequate infrastructure such as roads and the internet. Industrializing backward regions (Missions 1 and 3) thus depends on local capabilities and industrial policies. In addition, significant infrastructure works are an umbrella for industrial

[24] https://sdgs.un.org/goals

policies, as they demand industrial goods (e.g., chemical inputs, construction materials, and custom machinery and equipment) and engineering and R&D services.

The synergies among the six missions should be explored to maximize gains, as proposed by Sachs et al. (2019), of actions seeking to optimize the results of the SDGs based on their synergies — for example, investing in innovation (Mission 2) to produce wind turbines (Missions 1 and 6) and their electronic components (Missions 1 and 5) and installing them in the Northeast of the country (Missions 3 and 4). Note that infrastructure can also contribute directly and indirectly to all six missions and generate many jobs and high social return externalities.[25]

Table 6: Main industrial policy missions

Missions	Motivation
1.Reindustrialization and industrial revitalization	Brazil prematurely deindustrialized in a very intense way in the last 40 years. In this period, the growth rate has been stagnant. Furthermore, the populous and backward regions have never reached a moderate degree of industrialization. Nevertheless, these regions have the potential to advance in the industrialization of sub-sectors that do not compete with the South-Southeast, where the labour cost is relatively expensive. SDG 9 aims to promote inclusive and sustainable industrialization. Revitalizing manufacturing through innovation, clean technologies, and integration with new I.T. services, in addition to industrializing backward areas, can unlock the country's economic growth.
2. Innovation promotion, technical progress, and creation of dynamic comparative advantages	Scale intensive, specialized suppliers and science-based manufacturing sub-sectors lose share in Brazil's productive structure and export basket, even though they are the most innovative and dynamic of capitalist economies. Brazil patents and innovates little, despite having all the coordinated National Innovation System (NIS) actors. Innovation indicators have been stagnant since the early 2000s when the Innovation Surveys systematically measured them.[26] SDG 9 aims to foster innovation. Innovation diffuses technical progress, sustains productivity growth in dynamic terms, and drives the share of employment (for the sub-sector of origin and the sub-sectors benefiting from adoption/diffusion).
3. Boost employment and its formalization and reduce social and	Brazil has a high unemployment rate of 11.1%. Only half of the country's jobs are formal. The informality degree is even more significant in the most backward regions. SDG 8 aims at full and productive employment and decent work for all, and SDG 10 seeks to reduce income inequality within and among regions.
4. Increase investment in infrastructure	This kind of investment generates a high long-term social return. The country's level of infrastructure investments has been low in the last 25 years, and in the previous three years, it has been below the depreciation rate. Brazil has a shortage in several areas; for example, 16% of the population does not have access to treated water, 47% does not have access to a sewage system[27], and the rail transport network per km^2 is low for a continental country. These percentages are higher in lagging regions. SDG 9 also includes building resilient infrastructure, and SDG 6 aims to ensure availability and sustainable management of water and sanitation for all.
5. Moving forward in the digital economy	A new industrial revolution is underway by combining several technologies of the so-called Industry 4.0. New digital technologies have the potential to revitalize almost all manufacturing sub-sectors, as Andreoni (2018) showed. In addition, information services technologies are increasingly contributing to expanding the technological frontier, and the country that strengthens them can take advantage of the opportunities opening up.
6. Take actions to make the economy greener and sustainable	There is a solid global trend to make the economy green and sustainable, with relevant implications for international manufacturing competitiveness through trade agreements and pressure from societies for carbon-neutral production processes and more efficient products. New competitive parameters are emerging, such as the repairability index to French products like the energy efficiency label required in several countries. Goals 12, 13, and 15 of the SDGs are directly related to decarbonization, reduction in CO_2 emissions, protecting forests, and climate change.

Source: Authors' elaboration

It is worth mentioning that Brazil has already had successful examples of combining these missions. First, it turned the Midwest region (Brazilian savannah) into a large modern agricultural producer based on technologies[28] developed by

[25] As to the public investment in infrastructure, the case for boosting such public investment goes beyond the short-term effect of Keynesian fiscal multipliers. As Furman and Summers (2020: 34) argue, in virtue of its high externalities, "from a supply-side perspective, public investment can also offset some, all or even more than all of its cost if it has a sufficiently high rate of return in expanding the economy's potential itself. More important for a broader set of policies, public investments that have a rate of return in excess of the interest rate can repay themselves in present value terms."

[26] 2018 R&D expenditure (% of GDP) is still low in Brazil (1.16%) compared to the World (1.73%), China (2.14%), the US (2.83%), Germany (3.13%), Japan (3.28%) and South Korea (4.53%) according to UNESCO data.

[27] Data from the National Healthy Sanitation Information System, released in 2020 and referring to 2018.

[28] For example, correcting soil acidity and genetic improvement of seeds, adopting new fertilization practices, soil management, and pest and disease control.

Embrapa in partnership with public universities (Andreoni & Tregenna, 2020; Mazzucato & Penna, 2016). Second, it developed and used sugarcane ethanol as an alternative to gasoline in the 1970s, 1980s, and 1990s and developed flex-fuel engines (ethanol and petrol) for cars in the 2000s (Mazzucato & Penna, 2016). And third, Petrobras's technology programs have extracted offshore oil in increasingly deeper waters with several world records since 1979 (Mazzucato & Penna, 2016). These three examples and the State's action via public research institutes and sub-sectoral regulation mentioned in Subsection 3.2 show that Brazil can coordinate, define and obtain good results with the missions. But for this to continue, it is necessary to establish priorities since a large share of public R&D resources are not yet results-oriented (De Negri, 2021). Note that the country's industrial policies under the Workers' Party governments (2003-2016) have received criticism for their lack of selectivity and disconnection with the macroeconomic policies; consequently, the six missions focus on industrial policies.

4.2 Target sub-sectors linked to priority missions

We selected sub-sectors targeted by industrial policy considering the priority missions and simulation parameters related to the three kinds of jobs (overall, green, and tech jobs) shown in Subsection 3.2.1. Below is the list of sub-sectors:

*Health and pharmaceutical complex (*Missions 1 and 2*)*. Brazil has many key players in the health innovation system, such as public research institutes (Fiocruz and Butantan), big pharma companies with foreign and national capital and the strong purchasing power of the State through the Unified Health System (SUS acronym in Portuguese). In this complex are science-based industries (pharmaceutical and chemical), specialized suppliers (medical-hospital equipment) and scale-intensive manufacturing (plastics linked to hospital supplies). Based on biodiversity, the country can be a world authority in tropical diseases and pharmaceuticals (biotechnology). In addition, the ageing of the population will enable the expansion of residential care activities that are labour intensive (Mission 3).

- *Reindustrialization of niches with more significant potential to generate tech jobs and dynamic comparative advantages* (Missions 1 and 2). Policymakers can select a few niches from science-based, specialized suppliers and scale-intensive manufacturing. For example:
    - Chemical inputs such as fertilizers and pesticides, since the country has a high trade deficit and substantial agricultural demand.
    - Aerospace industry niches, as there are already productive and technological capacities from Embraer – a leading company in the value chain that produces regional jets and is entering the flying car segment – and ITA.
    - Develop the entire electric motors and batteries chain for electric vehicles, including the charging infrastructure (Missions 1, 2, and 4). Note that all the world's largest automakers have factories in Brazil.
- *Industrialization of backward regions, especially in more populated areas in the North and Northeast* (Missions 1 and 3). The State can encourage industrialization from peripheral areas where labour is still cheap through labour-intensive and resource-based manufacturing. In the more peripheral regions, they will need a mix of policies, such as expanding infrastructure (Mission 4), income transfers to create markets (Mission 3) and professional training and innovation policies (Mission 2). It is noteworthy that income transfers via successful programs such as Bolsa Familia or Emergency Aid used during the pandemic have a high marginal propensity for mass consumption linked to the sub-sectors of food, clothing, footwear, construction, and retail trade, which are all labour-intensive ones (Mission 3).
- *Improve the quality of education* (Missions 2 and 5). The country has made a great effort to universalize education in recent decades; however, the results obtained in the Program for International Student Assessment (PISA) remain very weak. According to UNESCO 2018 data, the average years of schooling (age 25+) in Brazil is 7.98, which is still low compared to advanced countries (14.08 in Germany and 13.50 in the US). Improving the quality of education is, directly and indirectly, related to all missions, especially innovation.
- *Information services, mainly software* (Missions 2 and 5). Currently, information services invest in R&D as much as in more technologically sophisticated manufacturing (Galindo-Rueda & Verger, 2016) and play a vital role in the leading technologies of the digital economy – such as artificial intelligence, machine learning, cloud computing, advanced robotics, virtual reality, etc. These technologies can revitalize manufacturing (Mission 1) due to the growing symbiosis between industry and services. Information services have a transversal role, contributing to raising productivity throughout the economy.
- *Sub-sectors linked to infrastructure expansion and green economy* (Missions 1, 2, 4 and 6). For example:
    - Capital goods on demand are linked to social infrastructure (human transportation such as subways and commuter rail) and physical infrastructure (freight trains and port equipment).
    - Telecommunications equipment is linked to the expansion of technological infrastructures, such as the 5G network. Expanding the coverage and speed of the broadband network can reduce regional inequalities (Mission 3), allow society to adapt more quickly to digital technologies (Mission 5), and enable new business models in peripheral regions.
    - Chemical inputs and plastic products are linked to the expansion of basic sanitation.

- Energy generation, transmission, and distribution equipment, including clean energy such as photovoltaic panels and wind turbines (Mission 4).

Frequently, Brazil is at risk of an energy crisis due to the low levels of the water reservoirs that maintain the hydroelectric plants. Therefore, the country needs to expand and diversify its energy matrix. Solar and wind energy are great alternatives because the country has the highest rate of solar irradiation in the world. Since its coastline is quite extensive and concentrates the population and economic activity, this facilitates the generation and transmission of wind energy. And to reduce the intermittency problem, the country can use the vast structure of hydroelectric plants as a backup to wind and solar production.

All the above policies generate jobs, especially those linked to infrastructure expansion, income transfers, and the industrialization of light industries in backward regions. In addition to these, two other policies are capable of increasing employment. The first is linked to incentives to the construction sector that could be adopted in the immediate post-pandemic period, which indirectly impacts many sub-sectors – such as non-metallic minerals, wood products, metallurgy, plastics, and engineering services. Through sectoral regulation, the government can also demand greener buildings, for example, with incentives for solar panels and more sustainable materials. The second, which is more structural in the medium to long term, will depend on advances in innovation, trade policy, and improvement in the business environment to increase the manufacturing exports' global market share, which is currently below 1%. Brazil should have goals to increase the market share of exports globally, including in the less high-tech sub-sectors where the country has comparative advantages, but the international presence is still low.

The State can also act via sub-sector regulation to accelerate the necessary changes toward environmentally sustainable investments with regulatory frameworks for residential construction and infrastructure. In addition, the State can further raise technological and environmental efficiency requirements in sub-sectors dominated by multinational companies, such as the automobile industry.

5. Conclusions

Deindustrialization is one of the most researched topics in economics in the last decades, but it has not equally affected countries worldwide. In developed countries, deindustrialization is driven by technological progress and manifested in the drop of the share of manufacturing employment in total employment. Yet, in most developing countries, deindustrialization has prematurely accelerated, except for a few where this phenomenon has not occurred. For example, in Asian countries, both the value-added manufacturing share in total GDP and the employment share in overall employment increased between 1970 and 2017; in Latin American countries, these results were in opposition.

Since the information and communication revolution circa the 1970s, there have been growing medium and high-tech activities in tradable services. In addition, the current digital economy revolution (Industry 4.0) brings several creative but job destructive technologies such as robotics, artificial intelligence, the internet of things, big data, 3D printing, nanotechnology, among others. As a result, many analysts anticipate that there will be radical job destruction and the transformation of the global world into a service economy. However, Industry 4.0 tends to integrate with manufacturing throughout the twenty-first century rather than merely interact. Therefore, it is more appropriate to understand this latter sector and the medium and high-tech services as an ecosystem of complex technologies that generate dynamic feedback rather than isolated activities. This means that the role of manufacturing as an engine of growth could be reduced but not eliminated since it will continue to act as the primary source of generation and diffusion of technical progress (Aiginger and Rodrik, 2020). Moreover, although new technologies are labour-saving, the actual impact of the digital revolution on employment is not so evident in the long run.

In Brazil, particularly, premature deindustrialization began in the mid-1980s, accelerated in the following decades, and manifested much more as a fall in the manufacturing value added in total GDP than as a significant drop in its employment share. Since the early 2000s, macroeconomic policies extremely unbiased toward price stabilization vis-à-vis sustaining economic growth oriented to catching up have been responsible for stagnant labour productivity and sluggish growth.

Most empirical studies calculate the degree of premature deindustrialization based on aggregate calculations of the share of manufacturing value added in total GDP or manufacturing employment in overall employment. However, recent empirical estimates at a sub-sectoral level conclude that the most innovative manufacturing groups like machine and equipment and science-based manufacturing segments are not deindustrializing in value-added and employment shares (Tregenna and Andreoni, 2021; Dosi, Riccio, and Virgilitto, 2021). Therefore, industrial policy for the most innovative sub-sectors may be able to reindustrialize middle-income countries like Brazil.

Based on the theoretical discussion on industrialization and premature deindustrialization as well as several empirical pieces of evidence on Brazil’s economic stagnation over the last decades, we proposed a mission-oriented industrial policy to boost labour productivity growth and restore Brazil's catching-up trajectory. We suggested the following six missions: (i) Reindustrialization and industrial revitalization; (ii) Innovation promotion, technical progress and creation of dynamic comparative advantages; (iii) Employment, job formalization, and reduction of social and regional inequalities; (iv) Boosting investment in infrastructure; (v) Integrating Brazilian activities into digital technologies; and (vi) Gradually replacing technologies with high carbon dioxide (CO_2) emissions for lower ones. We also identified sub-sectors for industrial policy based on the types of jobs (overall, tech and green jobs) generated by empirical simulations and linked them to the six missions. The Brazilian State can accelerate the necessary changes towards an environmentally sustainable economy and a less socially and regionally unequal one with regulatory frameworks for infrastructure and the automobile industry. It can also become more entrepreneurial. After four decades of economic stagnation and regression, Brazil cannot lose any more time.

We hope that the missions and policy suggestions are helpful for similar developing countries that have faced premature deindustrialization and stagnation in the last decades, including many countries in the Global South.

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Appendix - Table A1: Classification adopted

Classification	Industry	Code ISIC 4
Primary goods	Agriculture, forestry and fishing	01-03
	Mining and quarrying	05-09
Resource-based Manufacturing	Food products, beverages and tobacco	10-12
	Wood and products of wood and cork, except furniture	16
Labour-intensive manufacturing	Textiles, wearing apparel, leather and related products	13-15
	Fabricated metal products, except machinery and equipment	25
	Furniture, other manufacturing	31-32
	Repair and installation of machinery and equipment	33
Scale intensive manufacturing	Paper and printing	17-18
	Coke and refined petroleum products	19
	Rubber and plastics products	22
	Other non-metallic mineral products	23
	Basic metals	24
	Motor vehicles, trailers and semi-trailers	29
Specialized suppliers manufacturing	Electrical equipment	27
	Machinery and equipment n.e.c.	28
	Other transport equipment	30
Science-based manufacturing	Chemicals and chemical products	20
	Basic pharmaceutical products and pharma preparations	21
	Computer, electronic and optical products	26
Construction and energy infrastructure	Electricity, gas, steam and air conditioning supply	35
	Water supply; sewerage, waste management and remediation activities	36-39
	Construction	41-43
Low and medium-skilled services	Wholesale and retail trade	45-47
	Transportation and storage	49-53
	Accommodation and food service activities	55-56
	Real estate activities	68
	Administrative and support service activities, except for rental and leasing activities	78-82
	Arts, entertainment and recreation	91-93
	Other service activities	94-96
	Activities of households as employers of domestic personnel	97
High-skilled services	Information and communication	58-63
	Financial and insurance activities	64-66
	Professional, scientific and technical activities	69-75
	Rental and leasing activities	77
	Public administration and defence; compulsory social security	84
	Education	85
	Human health and social work activities	86-88

Source: Authors' elaboration based on Pavitt (1984) and Dosi, Riccio, and Virgilitto (2021).