



INDUSTRY 4.0 IN BRAZIL AND THE CHALLENGES OF THE PRODUCTIVITY OF THE ECONOMY

Indústria 4.0 no Brasil e os desafios da produtividade da economia

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ABSTRACT

This article has the aim to present the on going process of development of the Industry 4.0 in Brazil from the data analysis provided by recent relevant research and releases that deal with the field, considering for this a wider context analysis. This analysis includes the challenges of Brazilian productivity of the economy and its impacts in the transformation industry, being the most crucial, the phenomenon of the deindustrialization in Brazil, the low qualified workforce, the weak orientation towards innovation and technological development. It is concentrated not only in the technological aspects and manufacturing management related to Industry 4.0, but also explores the issues of productivity of the economy, sector performance and international comparisons. It seeks to demonstrate the importance of the binomial innovation and productivity to Brazil's insertion in the fourth industrial revolution. It is discussed the need for a new industrial and technological policy that also includes the labour training in STEM areas - science, technology, engineering and mathematics and, biological, aiming to induce the technological innovation. The demands of Industry 4.0 can be a strategic motto for the reallocation of employment among the economy sectors, aiming the increase of aggregate productivity in Brazil and the promotion of innovation.

Keywords: Industry 4.0; Innovation; Industrial Policy; New Competences; Productivity; Competitiveness.

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INDÚSTRIA 4.0 NO BRASIL E OS DESAFIOS DA PRODUTIVIDADE DA ECONOMIA

Industry 4.0 development in Brazil and the challenges of the productivity of the economy

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RESUMO

Este artigo tem como objetivo apresentar os processos em curso de desenvolvimento da Indústria 4.0 no Brasil a partir da análise dos dados fornecidos por recentes pesquisas relevantes e lançamentos que tratam da área, considerando para isso uma análise de contexto mais ampla. Esta análise inclui os desafios da produtividade brasileira da economia e seus impactos na indústria de transformação, sendo os mais cruciais, o fenômeno da desindustrialização no Brasil, a mão de obra pouco qualificada, a fraca orientação para a inovação e o desenvolvimento tecnológico. Concentra-se não apenas nos aspectos tecnológicos e gestão da manufatura relacionados à Indústria 4.0, mas também explora as questões de produtividade da economia, desempenho do setor e comparações internacionais. Busca demonstrar a importância do binômio inovação e produtividade para a inserção do Brasil na quarta revolução industrial. Discute-se a necessidade de uma nova política industrial e tecnológica que inclua também a formação de mão de obra nas áreas STEM - ciência, tecnologia, engenharia e matemática e, biológica, visando induzir a inovação tecnológica. As demandas da Indústria 4.0 podem ser um mote estratégico para a realocação de empregos entre os setores da economia, visando o aumento da produtividade agregada no Brasil e a promoção da inovação.

Palavras-chave: Industry 4.0; Inovação; Política Industrial; Novas Competências; Produtividade; Competitividade.

INTRODUCTION

According to Brazilian Chamber of Industry 4.0 (I4.0 Chamber, 2021) the incorporation of technologies 4.0, such as additive manufacturing, advanced robotics, big data, data analytics, internet of things – IoT and the artificial intelligence, have the potential of significant gains of productivity for Brazilian industry. In this sense, the study of Brazilian Agency of Industrial Development (ABDI, 2017) emphasizes that the adoption of the technologies of the fourth industrial revolution by Brazilian industry, could provide a saving of R\$ 73 billion per year (approximately US\$ 14 billion). The potential economy with predictive maintenance of machinery pool is estimated around R\$ 35 billion (approximately US\$ 7 billion), and the gains of productive efficiency are estimated at R\$ 31 billion (approximately US\$ 6 billion), added to the saving of energy, with the importance of R\$ 7 billion (approximately US\$ 1,4 billion) per year. Brazil presents great challenges to be solved in order to ensure its proper integration in the international scenario.

The national infrastructure of internet is still insufficient due to the lack of universalizing of broadband access and the index of velocity and network latency which are lower in comparison with developed countries. Brazilian labor force requires the development of necessary skills and competences to the demands of Industry 4.0. since the dissemination of knowledge and qualification of information technology and communication among Brazilian people are in a level far below expectations, being urgent the necessity of school curricula, professional training to the market needs and the sociobehavioral competences aiming the future. In the regulator field and incentives of the adoption of 4.0 technologies by industry, government, regulator and legislators need comprehend that technologies change and develop fast, requiring, therefore, public policies that can be suitably adapted to the future developments of technological evolution.

The protection of privacy is no less challenging, without, however, make unfeasible the benefits of society based on data, in addition to strengthen cybersecurity, mainly in contexts of intelligent cities and critical infrastructure, which use widely internet of things technology – IoT and big data resources. According to Brazilian Chamber Industry 4.0 (I4.0 Chamber, 2021), the biggest challenge is to promote the adoption of 4.0 technology in small and medium companies – PME, justifying the argument and mentioning that in accordance with OCDE – Organization of Cooperation and Economical Development, the PME use six times less software and technology for collecting and analyzing data than great companies. There are several probable causes: less availability of resources, lack of trained professionals able to dedicate themselves to the adoption of new technologies, lack of knowledge of the causes of the problems and their possible technological solutions, lack of estimate of the return on investment in technology, aggravated by the belief or perception that such projects are costly and complex to execute. Brazil needs to face the challenges promoted by the adoption of Industry 4.0 technology in order to avoid a worse process of deindustrialization, delay its economic development and affect the global competitiveness of its economy.

In the fourth industrial revolution, the information technology becomes the central point for businesses and make the technological competition the heart of economic development (Graglia; Huelsen, 2020). The emphasizes the decision of Brazilian government to launch a positive agenda and create a working group for Industry 4.0, named GTI 4.0, with more than 50 institutions such as government, companies, organized civil society etc., with the main objective to make contributions and debates about the distinctive perspectives and actions for Brazil to align itself to the great industrial and technological powers (Brazil-Germany Engineering Association, 2018). Among the premises established for the Industry 4.0 agenda in the period 2017-2019, the most prominent are: the support to private initiatives that enable and empower the private investment; test, evaluate, debate and build consensus through validating pilot projects; balance support measures for small and medium companies with great companies.

The path to increase the protagonism of Brazilian industry, presupposes the strengthening of public-private partnerships to ensure the basis of financing the resumption of industrialization. Due to the fast progress in the most developed countries in terms of the use of technology, in special the USA, Germany and China, Brazil cannot remain inactive, at the risk of increasing even more the technological gap regarding the countries that are in the race for Industry 4.0. For this reason, there is an urgent need for a national strategy about the topic. Brazil needs to increase the investments in physical and digital infrastructure. The physical infrastructure in Brazil has been presenting a historical deficit. The development and adoption of advanced technologies,

including smart automation and artificial intelligence, has the potential not only to increase the productivity of the economy and the growth of the gross domestic product - GDP, but also to improve the welfare of the population. In order to achieve such benefits and reduce the disruption impacts associated to the fourth industrial revolution and its potentially destabilizing effects in society, it will require an emphasis on innovation-led growth and careful management of workforce and other transitions related to the adoption and diffusion of technology, clearly in a complex and developing country such as Brazil (Bughin *et. al*, 2019).

According to the master plan 2017-2019 from Industrial Innovation and Research Brazilian Association (Embrapii, 2018), one of Brazil's great challenges is to increase the competitiveness of national industry, which depends a lot on its innovative capacity and on the increase of productivity in all the major sectors of the economy. In the document is addressed that the challenge for Brazil is not only regarding the increase of business investments in research, development and innovation (PD&I), but, most of all, by the encouragement of projects with bigger and better technological content, resulting in adding more efficient barriers against competition, producing more relevant economic impacts.

In order for Brazil to be inserted in the global production chains, with products and services of higher added value, there is an urgent need for a greater role in RD&I. Such insertion is reflected in the technological densification of the trade balance, which can positively impact the equation of social and economic development in Brazil. Research by the National Confederation of Industry (CNI, 2020a), indicates that Brazil is still in penultimate place in the general ranking of Brazil Competitiveness survey, among 18 selected economies, according to the criteria of being economies with similar characteristics to Brazil, or that compete with the country in the global market, such as: South Africa, Argentina, Australia, Canada, Chile, China, Colombia, South Korea, Spain, India, Indonesia, Mexico, Peru, Poland, Russia, Thailand and Turkey. Brazil is ahead only of Argentina and just behind Peru. Brazil is not among the top six (top third) in any of the nine competitiveness determinants that were evaluated. Brazil's most critical situation is in the Financing factor, which reflects the high costs. The situation is also critical in the Taxation factor, i.e., Brazil is the penultimate position among the 18 countries, with the second highest tax burden and the lowest quality tax system.

With regard to the Macroeconomic Environment and Business Environment factors, Brazil is in the penultimate position, which impacts the willingness of entrepreneurs to make new investments. Brazil is also among the last placed in the ranking of the factors Infrastructure and Logistics and Education. In Education, despite Brazil having the second highest public spending on education as a proportion of GDP (5.6%), the results in the dissemination and quality of education are unsatisfactory. Brazil decreased its disadvantage to the other competing countries in the sample of countries surveyed in the factors: Labor, Productive Structure, Scale and Competition and Technology and Innovation, in which it occupies the middle third of the ranking (9th, 12th and 8th position, respectively). In the Technology and Innovation factor, in relation to the set of 18 countries that make up the sample, Brazil reached the fifth highest investment in research and development (R&D) as a proportion of GDP (1.26%), well below that reached by South Korea (4.55%) and China (2.13%). By way of comparison with developed countries with higher per capita income, Brazilian situation is even weaker: Japan (3.5%), Germany (2.9%), the United States (2.8%), and France (2.2%) (Pinheiro; Figueiredo, 2017). Compared to the revised 2018-2019 ranking, Brazil retreated in the Labor and Education factors, while advancing one position in the Business Environment factor. All in all, Brazil's overall average rose. The average of the scores obtained in the nine factors rose from 4.26 to 4.4 (up 3.2%), showing that Brazil's situation improved, but not enough for the country to advance in the overall ranking.

The methodology for the development of this article, comprised a broad bibliographic review, theoretical references, such as books, scientific articles, electronic portals of agencies, internationally renowned consultancies, and Brazilian government studies, analysis of technical reports, analysis of statistical indicators, and review of historical stages about the economic development of Brazil, from a more multidisciplinary approach. The article follows a qualitative research line, aiming to focus on deepening the researched topic and the explanation of aspects of Brazilian industrial reality that exceed the domains of technology and manufacturing management, permeating the issues of economy's productivity, sectorial performance and international comparisons.

As for its main objective, the article is the exploratory type, with the aim of increasing the comprehension about the topic, according to the hypothesis that the Industry 4.0 can mitigate the low productivity of Brazilian economy.

1 INNOVATION AND PRODUCTIVITY

The context of Industry 4.0, emphasizes the importance of the binomial innovation and productivity aimed at the economic growth of countries, especially Brazil, given our poor performance in gross domestic product - GDP. Economic history teaches us the relevance of technological innovation as a driver of development in capitalist society but conditioned to productivity gains in the economy. The economy's productivity, in turn, is dependent on the pace and application of technological innovations (Gordon, 2016; Mokir, 2014; Mokir, 2013; Schumpeter, 1939). According to (Senna, 2017) the two concepts of productivity are considered relevant: labor productivity and total factor productivity (TFP). Regarding the latter concept, it refers to the portion of the economy's product growth not explained by the contribution of capital and labor. The digital revolution, in which Industry 4.0 is inserted, has changed the way in which the gross domestic product is divided between those who own labor and those who own capital. Not only in the case of Brazil, but of a set of 59 countries, there is a tendency for the participation of labor in the gross domestic product - GDP of the business sector to fall, and a marked process of concentration of income and wealth. More concentrated income and wealth tend to inhibit the propensity to consume, to the detriment of the dynamism of the economy (Brynjolfsson; McAfee, 2014; Karabarbounis; Neiman, 2013; Jaimovich; Siu, 2012; Cowen, 2011).

2 BRAZIL IN INTERNATIONAL PRODUCTIVITY COMPARISONS

Considering Brazil's performance in the two productivity concepts already mentioned, namely labor productivity and total factor productivity (TFP), we can say that our evolution is not the best (Bonelli; Veloso; Pinheiro, 2017). Based on it is asserted that Brazil's performance was good until 1980, but weak during and after the foreign debt crisis of the 1980s: Brazilian productivity was about a quarter of the US in 1950, reached almost 40% in 1980, and returned to about 25% from 2007 onwards. More recent data confirm the stagnation of Brazil's low productivity. According to Pastore (2019) the average Brazilian worker's productivity is just a quarter of an American worker and a third of a German or Korean worker.

2.1 Brazil and Latin America

Brazil's productivity between 1950 and 1980 grew 3.5% per year, higher, therefore, than the productivity of the rest of the Latin American countries, whose growth was of the order of 2.5% per year. Throughout the 1980s, both Brazil and Latin America had similar productivity declines, around 2% per year. In the 1990s and 2000s, productivity grew more in Brazil than in the rest of the Latin American countries. More recently, Brazilian productivity became worse compared to Latin American productivity, that is, while productivity fell by about 0.3 percent per year in Brazil between 2010 and 2015, it increased by 0.8 percent per year in the rest of the Latin American countries (Bonelli; Veloso; Pinheiro, 2017).

2.2 Brazil and developed countries

The following table compares Brazil's performance with the selected developed countries in the 1990s, 2000s, and 2010 through 2014. South Korea had the highest growth in total factor productivity (TFP) over the past three decades. In the United States, TFP growth was 0.7% per year in the 1990s and 2000s but has fallen to near zero since 2011. The United Kingdom has performed even worse, with negative TFP growth since 2001. Japan's TFP was virtually stagnant over the period, with the exception of 2001-2010, when it grew 0.5% per year. Brazil's TFP increased only in the 1990s, having fallen in the 2000s and especially in the recent period.

Table 1 Average total factor productivity growth rates in selected periods - Brazil and selected developed countries (% per year)

Countries	1991-2000	2001-10	2011-14
Brazil	0,8	-0,3	-1,6
United States	0,7	0,7	0,1
United Kingdom	0,4	-0,1	-0,4
Japan	0,1	0,5	0,0
South Korea	2,2	2,2	0,3

Source: (Bonelli; Veloso; Pinheiro, 2017)

2.3 Brazil and BRICS

The work in the following table highlights the performance of India and China, despite the slowdown from 2011 onwards. South Africa, meanwhile, has shown a decline in its total factor productivity (TFP) since 1990. Russia, despite falling in the 1990s, showed strong growth in the 2000s, decelerating in the recent period. The thesis about Brazil's historically low productivity is confirmed by comparison with the BRICS countries, with the exception of South Africa.

Table 2 Average growth rates of total factor productivity in selected periods - BRICS (% per year)

Countries	1991-2000	2001-10	2011-14
Brazil	0,8	-0,3	-1,6
China	1,5	4,2	0,7
India	1,0	1,8	0,7
Russia	-1,3	3,2	1,7
South Africa	-0,8	-0,3	-2,8

Source: (Bonelli; Veloso; Pinheiro, 2017)

The data presented aim to contextualize the challenges of such a big country as Brazil. The potential advances that Industry 4.0 can provide for the competitiveness of Brazilian companies, however, presuppose a broader analysis of the factors that affect good business performance in the country. Brazil has a huge productivity problem in its economy, the main reason for its low gross domestic product - GDP growth. From the data presented, we can argue that Brazil's development is more related to its ability to keep its productivity up, in a more stable way over time, instead of short but unsustainable cycles of high productive gains as it has been in recent decades. The implementation of the Industry 4.0 model can be decisive for the improvement of productivity through access to technologies and modern production practices, already available in more developed countries. For this purpose, Brazil must insert itself in a more strategic way in global value chains.

2.4 Brazil and a sectorial vision

Analyzing the Industry 4.0 movement in Brazil requires a deeper look into the productivity dynamics of Brazilian economy. An important feature of economic development is the process of structural transformation, defined as the moving the economic activity among different sectors over time. As a general rule, every economy experiences a reduction in the participation of the agricultural sector and an increase in the importance of the services sector in employment and in the gross domestic product - GDP over time. The relative participation of industry tends to rise initially, but later gives place to the service sector (Veloso *et al.*, 2017).

The following table presents sectoral productivity for Brazil and 10 selected countries at different levels of development. The added productivity of the United States is about 6 times higher than in Brazil, which highlights Brazil's great distance from the technological frontier. Although agriculture and cattle ranching is the sector with the highest productivity growth in Brazil in the last two decades, the productivity of the sector in the United States is still about 14 times higher than in Brazil. The productivity of American industry, in turn, is 5.7 times greater than in Brazil. The distance is similar in the case of services, with the United States having a productivity 5.4 times greater than in Brazil.

Table 3 Sectorial Productivity – Brazil and selected countries

Countries	Total	Agriculture	Industry	Services
Brazil	14.689	4.779	19.389	15.814
United States	89.318	66.271	109.937	85.647
Ireland	84.949	27.976	114.873	80.397
Australia	67.555	65.469	88.358	61.589
France	66.488	50.027	64.056	69.225
Japan	64.967	18.102	70.607	65.400
Great Britain	56.729	25.184	70.852	54.643
South Korea	52.503	24.290	74.759	44.429
Mexico	25.260	6.109	31.423	27.836
China	14.792	3.599	25.661	18.549
India	8.423	2.224	11.984	17.307
Average SEA	46.994	25.250	52.802	48.218
USA/Brazil	6,1	13,9	5,7	5,4
Average SEA/Brazil	3,2	5,3	2,7	3,0

Source: (Veloso *et al.*, 2017)

Note: Productivity is calculated from Socio Economic Accounts (SEA) data converted to international prices using PPP - purchasing power parity measures. Productivity data are expressed in US\$ PPP, using the added PPP. With the exception of Brazil, countries are ordered in descending order by total productivity. The highest productivities of each sector are marked in bold.

The data above indicates that Brazilian agriculture and cattle ranching is the least productive sector in Brazil, with about 33% of aggregate productivity, while industry, followed by services, have the highest productivity, but far behind the other SEA countries. This denotes an opportunity for reallocation of employment among sectors to increase Brazil's aggregate productivity, and Industry 4.0 may be a prominent lever for fostering higher skilled jobs and changing skill sets that are necessary for Brazil's international competitiveness, but in volumes lower than what industry used to generate.

The analysis of Brazil from its major sectors of economic activity helps us understand to what extent the low Brazilian productivity, compared to other countries, is associated with differences in the level of sectoral productivity or in the sectoral allocation of employment. The results indicate that Brazil's productivity is much lower than that of developed countries in the three major sectors: agriculture and cattle ranching, industry and services. Characteristic of the Brazilian economy, the low aggregate productivity results from the large proportion of labor in less productive sectors, such as agriculture and cattle ranching. As argued (Veloso *et al.*, 2017), the participation of agriculture tends to fall throughout the development process of countries, with a corresponding increase in employment in industry and services. This dynamic emphasizes the importance of the binomial innovation and productivity in the context of Industry 4.0. in Brazil, whose phenomenon of low productivity occurs in all sectors.

3 THE NEED FOR A FORWARD-LOOKING INDUSTRIAL POLICY

Throughout the 1980s and 1990s, debates took place about the desirability of countries maintaining and encouraging industrial policies. Renowned marginalist economists emphasized the harm of industrial policy, even pondering the low importance of industry in relation to other sectors of the economy. The general view of these economists was that the market would produce the most efficient allocations, while intervention via industrial policies would induce rent seeking practices (Miguez *et al.*, 2018).

According to Morceiro (2019), the Brazilian industry of transformation, which had led economic growth in the five decades preceding 1981 in the industrialization stage, lost dynamism from 1989 on. The result of this was the poor performance of the industrial sector in terms of economic growth, technological development, and export performance. Brazil faces a challenging process of stagnation in its technological development. Spending on research and development (R&D) as a proportion of the gross domestic product - GDP evolved timidly, from 1.05% to 1.28% in the period between the years 2000 and 2015, according to data from the Ministry of Science, Technology, Innovations and Communications of Brazil. In the same period, the indicator for China more than doubled, from 0.89% to 2.07%, aligning itself, therefore, with the technological efforts expended by the countries of the Organization for Economic Cooperation and Development (OECD). The technological effort of the

Brazilian economy is negligible and far from the OECD countries, especially those that are on the technological frontier, such as the United States (USA), Germany, Japan and South Korea. The innovation rate (innovative companies over total companies) of Brazilian manufacturing is also low and stagnant.

In their work, (Miguez *et al.*, 2018) highlight the importance of the manufacturing industry for economic growth, productivity growth and employment growth. This sector is the main source of productivity gains in the economy (Andreoni; Chang, 2016), configuring itself as a learning center of modern economies and a major inducer of innovations of a technological nature (Rosenberg, 1963). The authors call attention to the role of manufacturing as a source of organizational innovations and of demand for high productivity activities in the other sectors. It is worth mentioning the work of Prebisch (1949) that, since those distant times, had already alerted to the relevance of the manufacturing industry to overcome the balance of payment problems of the peripheral countries, as we can describe Brazil.

Another relevant aspect concerns the contribution of industry to the economy in terms of the profile of wealth distribution in society. By presenting a structure that includes medium-skilled functions and medium salaries, such as specialized machine operators, technologists and engineers, the relevance of industry in the GDP contributes positively, mitigating the situation of extremes between high and low wages, as occurs in the services sector (Tshidimba *et al.*, 2015).

The loss of dynamism of the Brazilian manufacturing sector generates concerns because the manufacturing industry is very much associated with technological innovations, the generation of trade surplus, the stimulation of economic growth and the elevation of the economy's productivity (Rodrik, 2016; Szirmai; Verspagen, 2015; Unido, 2015; Manyika *et al.*, 2012; Thirlwall, 2002) in addition to the promotion of regional development. Thus, we can argue that manufacturing acts as an engine of economic growth (Haraguchi; Cheng; Smeets, 2017; Su; Yao, 2017; Thirlwall, 2002) and acts as a ladder sector to stimulate economies, especially those not so developed as the Brazilian one, to reach better levels of development (Rodrik, 2014; Rodrik, 2013).

There seems to be a convergence, more recently, about the convenience of promoting industrial and technological policies, mainly as a response to the assumptions of the fourth industrial revolution, in which the whole field of Industry 4.0 is integrated. It is fundamental, however, that there are adequate macroeconomic conditions and a vision of the State, which considers the role of industry and its productive structure strategic for the economic and social development of the country. In this sense, historical experience shows that today's developed countries have used and still use specific policies to transform their production structure. There has been a deliberate effort by several countries to give prominence to their industrial sectors. The one that is considered the technological frontier, the United States (USA) undoubtedly, is a representative country on the adoption of industrial and technological policies in an intensive manner (Miguez *et al.*, 2018).

The 2007-2008 crisis highlighted the interest in industrial policies, especially considering the nature of manufacturing production (O'Sullivan *et al.*, 2013). In parallel with the rise and industrialization of China, one also notes an increasing fragmentation of production, i.e., goods are being produced in separate stages and, as the literature points out, in recent decades there has been a continuous growth in the trade of intermediate goods. As a result of the production fragmentation process, the structure of the global industry has changed in its attributes of location, governance, ownership of production, to mention the most relevant, showing the increased importance of some emerging countries. The phenomenon of product differentiation intensifies the fierce competition between countries and markets that are large but considered peripheral such as Brazil, India and China, for example, become the focus of attention of multinational companies. Added to this is the need for counterparts to operate in these markets, such as local content clauses, technology transfer and partnerships with companies, which generates an inductive effect of greater cooperation. A phenomenon to be highlighted in this context concerns the internationalization, by large companies, even if in a more modest way, of the production of knowledge and innovation (Miguez *et al.*, 2018).

The literature on industrial and technological policy experiences by countries highlights the use of enabling technologies, which help form a broader and more consistent knowledge base, from which more specific and particular applications of other technologies can be developed. The focus on these so-called enabling technologies, is present in important initiatives of leading countries such as the cases of the Advanced Manufacturing Initiative in the US, the High-Tech Strategy in Germany, Foresight in the UK, Nouvelle France

Industrielle in France, Made in China 2025 in China and Make in India in India (IBEF, 2021; Arbix *et.al*, 2018; Rondon; Bin, 2017; Daudt; Willcox, 2016; Andréine, 2013).

In the Brazilian context, there is no shortage of discussions about the country's deindustrialization, which have intensified since the assumptions of Industry 4.0, and the movement that has been triggered in the protagonist countries, for the encouragement of the modern manufacturing industry. The indicators on the performance of Brazilian economy and its industry attest to the relevance of the debate on the challenges of deindustrialization in Brazil. In the 1980s and 1990s, the average growth rate of Brazilian economy was around 2.9% p.a. and 1.7% p.a., while in the 2000s it was 4.1% p.a., In 2010 Brazilian economy suffered a strong deceleration, with an average growth rate of around 1.7% p.a. between 2011 and 2014, with two consecutive years of recession in 2015 and 2016, with rates of -3.8% and -3.6%, resulting in an accumulated loss of 7.4%.

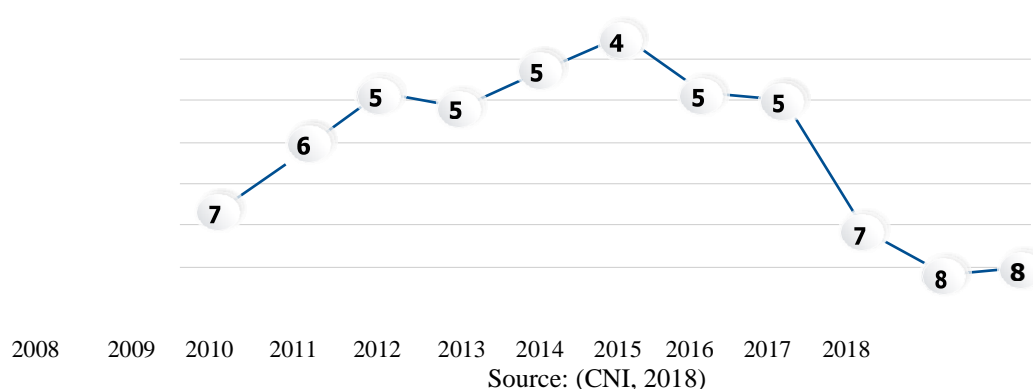
It should be highlighted that the positive results of Brazilian economy in the 2000s positively impacted the manufacturing industry. However, this growth rate was lower than that of the economy as a whole, of only 2.7% p.a. for the entire period 2000-2010 and 3.1% p.a. for the period 2003-2010. The results in the years 2010 are even more disappointing, with average negative rates in the period 2011-2014 of -1.4% p.a., which deteriorated further in the years 2015 and 2016, respectively and worryingly -10.4% and -5.2%. Combined the results presented from the years 2010, the value added of industry has receded by almost a fifth of its value cumulatively.

On the import demand side, Brazil grew significantly in the period, declining only from 2014 onwards. In the period 2003-2014, imports of industrial products grew 15.4% p.a., a movement from US\$ 40.5 billion to US\$ 196.7 billion. Such results led Brazil to show growing deficits, notably in higher value-added products. The growth trajectory of imports by Brazil cooled only in 2015 and 2016, respectively 23.4% and 17.6%. It is clear that Brazilian industry faces serious competitiveness problems, which may be related to macroeconomic issues, more specifically the instability of the exchange rate and its use for inflationary control, as well as structural issues within the Brazilian industry itself, characterized by low rates of investment in fixed capital and low investments in innovation.

A modern industry fosters the demand for skilled labor and investment in product and process innovation, in addition to triggering economic effects on other sectors, such as high value-added services. Given the challenges faced by industry, it is essential that the country strengthen its industrial base through a technological and industrial policy, compatible with what has been developed within the scope of the fourth industrial revolution by the protagonist countries already mentioned, as well as organize efforts for more intense cooperation with multinational companies already installed (Miguez *et al.*, 2018).

3.1 Brazil's position in the global competitiveness ranking

Figure 1. Productivity in Brazilian industry



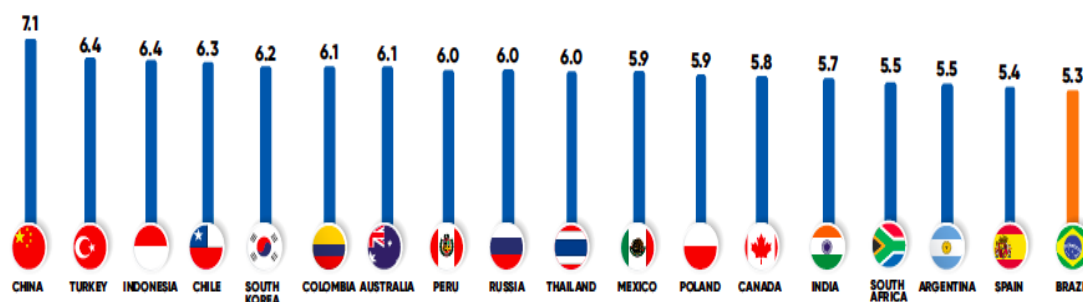
Productivity is a major determinant of competitiveness. Over the past ten years (2006-2016), Brazil recorded the worst evolution in productivity among its 10 main trading partners. According to (CNI, 2018) during this period labor productivity in Brazilian industry increased by 5.5%, while in the US it grew by 16.2% and in Argentina by 11.2%. This

causes the Brazilian industry to lose competitiveness both in the international and in the domestic market, where imports from its competitors have been on the rise.

3.2 Ranking of the macroeconomic environment factor

Solid macroeconomic fundamentals reduce uncertainties about the future and increase investor confidence. In order to improve Brazil's competitiveness, it is importante to promote favorable conditions for a significant increase in the investment rate, which remains lower than that recorded in other emerging countries, including in Latin American countries.

Figure 2. Increasing the investment rates



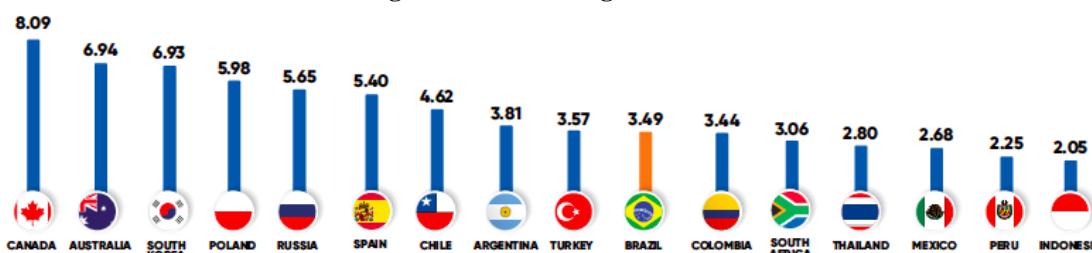
Source: (CNI, 2018)

Note: Mean scores (0 = worst performance; 10 = best performance)

3.3 Education ranking

Labor productivity is one of the main determinantes of industry competitiveness. Highly educated teams and continued training can lead to more effective solutions to every day problems, to better adapted products and productions processes and to the development and implementations of innovations. In Brazil, the unsatisfactory quality of basic education and the limited supply of technical and vocational training courses, constitute barriers to productivity growth and to the competitiveness of companies. Despite the existence of islands of excellence, higher education in Brazil is far from meeting the demands of the productive sector and the highest quality benchmarks in the world, which puts the country at a disadvantage in its ability to innovate and compete.

Figure 3. Level of higher education



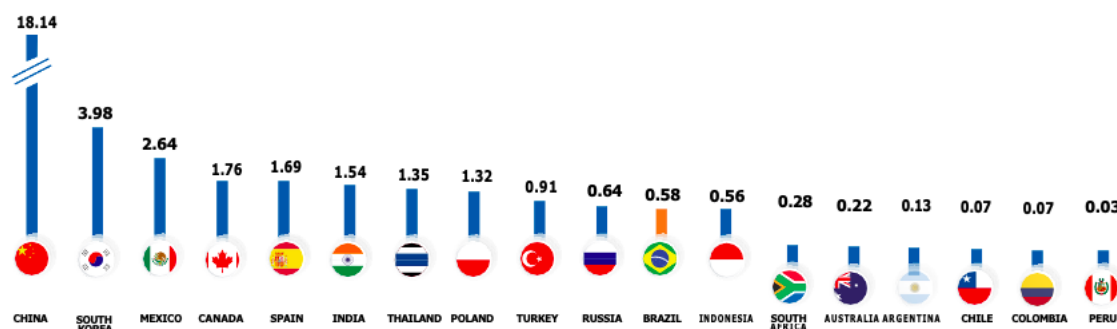
Source: (CNI, 2018)

Note: Mean scores (0 = worst performance; 10 = best performance)

3.4 Brazil's share in global exports of manufactured products (%)

Integrated industrial, innovation and foreign policies must be designed to remove obstacles and promote industrial growth, stimulate innovation and integration into the international market, seize competitive advantages, develop new skills and produce goods with greater technological content. Brazilian industry has been losing competitiveness in the international market. Brazil's share in global exports of manufactured products decreased from 0.82% in 2005 to 0.58% in 2015.

Figure 4. Global level of export manufacture

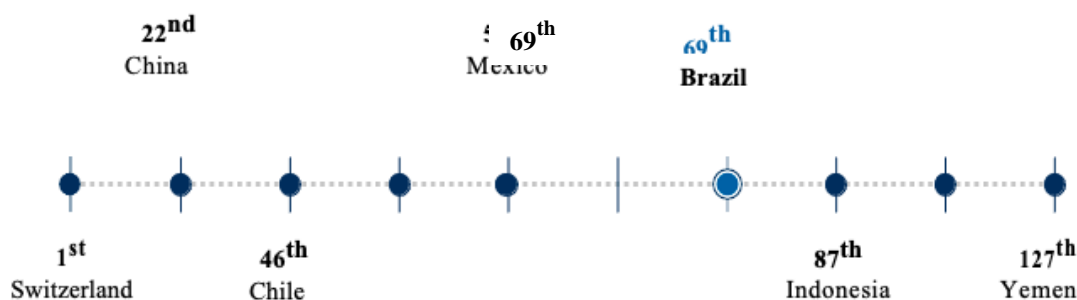


Source: (CNI, 2018)

3.5 Global innovation index (2017)

Adopting a consistent industrial and innovation policy is essential for industry to reach a new level of competitiveness. Innovation is the engine of long-term productivity gains. Once systemic inefficiencies are eliminated as a result of product and process innovation alone, productivity can grow steadily. Investing in innovation generates benefits for the economy as a whole, but the costs and risks inherent in innovative activities are exclusively borne by companies that invest in Research, Development and Innovation – RD&I. It is therefore necessary to create a regulatory environment designed to stimulate innovation, a technological support system and appropriate funding lines.

Figure 5. Investment in research development and innovation



Source: (CNI, 2018)

4 Opportunities and challenges of Industry 4.0 for Brazil

Industry 4.0 has the potential to transform and revolutionize current processes and dynamics, offering solutions to important challenges that directly impact national industrial productivity. Its transversality and agility bring opportunities to several industrial sectors. However, its development in Brazil involves a series of challenges that need to be overcome in order to reposition the country in the global value chains (I4.0 Chamber, 2020).

4.1 Opportunities

According to the MCTIC report (Federal Government of Brazil – Ministry of Science, Technology, Innovations and Communications, 2017) comprising 500 Brazilian companies, few of them perceive Brazil's

protagonism in advanced manufacturing in the global scenario or even in Latin America. At the same time, almost 80% of the respondents understand that advanced manufacturing is an opportunity for the productive development and for Brazilian society. This study indicated, besides the advantages that advanced manufacturing will provide in the increase of productivity (for 86.6% of the respondents) and in the decentralization of production (for 61.2% of the respondents), the companies' concerns with issues of social interest such as environmental protection (34.3% of the respondents), food safety (29.9% of the respondents), employment (23.9% of the respondents) and energy efficiency (64.2% of the respondents). The Brazilian business community associates the concept of advanced manufacturing mainly with smart products (72.5%), followed by networking and digitalization (68.1%), new business models (63.8%), automation (52.2%), product optimization (34.8%), and others (8.7%).

A previous study (Rossato, 2018) explains that from research conducted with over 700 Brazilian business leaders, Brazilian executives are preparing their companies and their workforce for the inevitable process of digitalization. Compared to the global average, Brazil has higher rates of developing new business models (44%), preparing the workforce for the digital future (98%), and using technologies to solve organizational challenges (22%). Moreover Studies by (PricewaterhouseCoopers, 2016) on Industry 4.0, indicate that 37% of Brazilian respondents expect emerging technologies to generate additional revenue for companies, 32% expect cost reductions, and 41% anticipate gains in efficiency by 2021.

Among the main economic opportunities arising from Industry 4.0, it is argued about the expected increase in revenues. There is an understanding that transaction costs can be reduced, with greater control and reliability over production processes, leading to higher productivity and competitiveness, greater industrial safety, better product quality, and greater customer involvement in production (CNI, 2017). Increased capital utilization is another important factor, notably for companies operating in developing countries, such as Brazil, where capital constraints can be a major barrier to technology upgrades (Unido, 2019); the decentralization of production process controls, interoperability, virtualization, real-time production and modular systems on the production line, define the main premises of the fourth industrial revolution in Brazil (Firjan, 2019).

4.2 Challenges

From the point of view of human capital, Brazil lives a vicious circle in the sense of its low inertia in the generation of higher qualified jobs, very influenced by the deindustrialization process that the country is going through, with relevant social impacts as attested by the unemployment and income inequality statistics available in electronic communication vehicles. The generation of jobs in volume and quality in Brazil, goes through the greater protagonism of the industry and requires a serious discussion about the professional training of Brazilians, to face the imperatives of Industry 4.0 (Graglia; Lazzareschi, 2018). In the review of the National Curricular Guidelines - NCGs of the undergraduate course in engineering, which came into force in 2019, there was recognition about the imperative need to prepare students to deal with the diversity of demands, design and develop technologies, undertake, solve complex problems with feasible solutions and navigate in the digital age. The reviewers of the National Curricular Guidelines for the engineering course emphasize that it is mandatory to value technical and social emotional skills throughout the training process, offering an education that makes sense to students and that motivates them to learn and evolve permanently (CNI, 2020b).

The Brazilian challenge of insertion in the fourth industrial revolution is immense and, therefore, it is necessary a new industrial and technological policy that also contemplates the incentive for the training of workforce in the fields of: STEM - science, technology, engineering and mathematics and, biological, which are more related to technological innovation (Morceiro, 2019). One of the characteristics of the fourth industrial revolution concerns the concentration of advanced digital production technologies in some more developed economies, called front runners. These dynamics of the competitive game, impose on a peripheral country like Brazil, a more secondary role, of follower in production, making even more complex the equation of economic productivity challenges faced by the country (Unido, 2019).

Based on MCTIC studies (Federal Government of Brazil – Ministry of Science, Technology, Innovations and Communications, 2017) concerns about Brazil's technological capacity for advanced manufacturing, which are associated with economic, political and cultural characteristics not adequately explored or addressed. Brazil is

a country of continental dimensions, with important regional asymmetries that are reflected in the structure of the national industry, through the coexistence of companies with varying levels of capacity and competitive performance in the most diverse productive systems (IEL, 2018). Furtado (2017) evaluates that the Brazilian industry is in search of a new industrial model, because, despite the significant advances of the Brazilian industrialization process, achieved throughout the 1950s and 1970s, it is evident that some limitations faced by Brazil, as a result of the economic policies adopted, have reduced the inductive potential of the Brazilian industrial park, which entails relevant challenges to the development of Industry 4.0 in the country today.

The first limitation refers to the industrial park formed until the late 1970s, which reproduced models developed in more advanced countries, with a predominance of sectors typical of the second industrial revolution, with emphasis on the metal mechanical and chemical sectors. While state-owned companies and multinationals occupied prominent positions, Brazilian national companies concentrated in areas considered as secondary. By the end of the 1970s, when the world began its transition to a new industrial pattern, the modest opening of the national industry to trade flows brought important limitations to Brazil, given that the international projection of the economies took place with a greater degree of intensity. Another important consideration about Brazilian industrial development, which constitutes an important challenge in the context of Industry 4.0, is the modesty of technological efforts, characterized by the reproduction of processes and products already existing in the market, a certain mimicry of what was produced and of the production models of other countries, but without the elements of technological dynamism necessary for Brazil (Furtado, 2017).

Brazil has not managed to build an electronic industrial system and its insertion in the advanced manufacturing in the context of Industry 4.0 constitutes a significant challenge for the country's economic agents, since it comprises different technological areas, physical or virtual integrated objects, connectivity or interoperability aspects of the objects, data and information enabling systems, integrators of different systems and intelligent internet service providers. Thus, the major concerns in the field of new technologies are: the management of information and knowledge, the internet of things and artificial intelligence, digitalization and cyber-physical systems, sensors, actuators and interoperability (Federal Government of Brazil – Ministry of Science, Technology, Innovations and Communications, 2017).

CONCLUSION

The present article has dealt with the Industry 4.0 development in Brazil from a broader context, beyond the attributes of industrial technology and manufacturing management, necessary, it is pondered, given the complexity and the economic idiosyncrasies of a country of continental dimensions such as Brazil, whose manufacturing industry share in the composition of the gross domestic product - GDP, has been decreasing steeply since 1989, which brought very significant structural consequences, such as the Brazilian deindustrialization phenomenon, the low qualification of the employed labor force, the weak orientation to innovation and technological development. Brazil needs an industrial and technological policy aligned to the assumptions of Industry 4.0, to help face the challenges of the low productivity of the Brazilian economy.

The imperatives of Industry 4.0 can be a strategic motto for the reallocation of employment among sectors, aiming at increasing aggregate productivity in Brazil and fostering innovation. The importance of the innovation and productivity binomial in the context of Industry 4.0 must be emphasized, especially in a country with the competitiveness challenges such as Brazil. The Brazilian manufacturing industry can still play a strategic role in the coming decades, to guide Brazil towards a development pattern that provides higher per capita income and better social indicators. However, it is clear that Brazil is in search of a new industrial model. An important challenge for Brazil in the context of Industry 4.0 is its modest technological efforts, which are characterized, above all, by the reproduction of processes and products already on the market, a certain mimicry of what was produced and of production models from other countries, but without the elements of technological dynamism necessary for a country whose economic productivity is low.

Having a competitive industry is crucial for Brazil's development. In this sense, it is necessary to create an industrial and technological policy oriented towards the future, which is guided by an integrated vision of the main challenges present in the various industrial sectors, with clear identification of the enabling technologies and the most promising industrial systems, through effective coordination, which ensures that Brazil is moving in

the right direction and does not fall into the temptation of short-term solutions that benefit isolated interest groups, as has been part of the history of Brazilian economic development. Brazil urgently needs to align itself internationally with efforts to identify the most appropriate technologies for the strengthening and relevance of its industry, enabling it to be a relevant player internationally, especially in view of the reshoring movement that has taken place in developed countries, and the development of new markets that allow Brazil to participate in global value chains.

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