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Industrial, Trade and Innovation Policies within the Perspective of Industry 4.0: The Case Portugal and Brazil

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Abstract

This study aims to identify the new contexts in which industrial, trade and innovation policies are being developed, with a focus on the changes inspired by the Fourth Industrial Revolution. The following questions will be investigated: What are the limits and impacts of industrial, trade and innovation policies from an Industry 4.0 perspective in Brazil and Portugal? The study is descriptive, being carried out through documental research and by using secondary data. As results, it highlights how industrial, trade and innovation policies in both countries were impacted by the crises that occurred in the period under analysis. Furthermore, there are limits to technological overflows and to an increase in the participation of both countries in global trade outside the logic of economic integration or insertion into blocks and free trade agreements.

Keywords: Industry policy • Trade policy • Innovation policy • Industry 4.0

Introduction

Reflecting a process that came from the late 20th century, the first two decades of the 21st century witnessed an accelerated evolution of the new information and communication technologies in the most diverse countries and regions, which had a profound impact on industrial and trade structures, and it is still far from its end. Thus, it is not surprising that the literature is becoming replete of studies [1-4]. Focusing on the implications of advances in fields such as automated intelligent systems, robotization and additivation-fabrication, and data analysis related to new digital technologies associated with the Fourth Industrial Revolution (4IR). In this context, an emphasis is being placed on artificial intelligence systems, cloud and proximity computing, block chain technology, 5G technologies and the Internet of Things, which together constitute one of the main pillars of digital transformation. Also, this evolution requires a higher level of the debate on how government programs should interact with productive structures to boost the process. Given the importance acquired by opening up to foreign markets for most economies, particularly as a way to encourage the competitive reinforcement of domestic firms and sectors, it is critical to look at the relationship between industrial and trade policies and understand how it can foster innovation in this new and complex environment.

One of the most convincing examples when outlining the role of the new industrial policy in Portugal derives from the Industry 4.0 Program formulated in 2016 and implemented in 2017 along the following pillars: training of people, technological cooperation, creation of Industry 4.0 startups, financing, investment support, internationalization and legal and regulatory adaptation. In 2020, of the 64 measures contemplated in this initiative, 95% had already been executed in Phase I, involving more than 24.000 companies and 10.000 workers. With more than 2.26 billion euros of incentives from European funds through Portugal 2020, there is a forecast to impact about 50.000 companies and train more than 20.000 workers in digital skills, foreseeing to inject in the economy up to 4.5 billion euros of investment in the next 4 years. For example, the "Portugal i4.0 Platform" project is co-funded by COMPETE 2020 under the Collective Actions Support System and contemplates an investment of 3.5 million euros, corresponding to an incentive of 2.9 million euros (COTEC, 2018).

In Brazil, industrial policies directed to Industry 4.0 have been gaining relevance in sectorial projects, business associations and empirical studies, as illustrated by CNI (2020) in a survey in 2019 regarding the diffusion of Industry 4.0 technologies: a) smaller companies are further behind in the process of implementing Industry 4.0; b) the origin of the companies' capital is not a determining factor for the implementation of new technology; c) the percentage of foreign companies that have not implemented Industry 4. 0 projects (40%) are very close to the national companies (50%); d) Industry 4.0 enters the companies through the automation of production and the increase in productivity is the main motivation; e) another motivation for implementing Industry 4.0 is the reduction of energy costs, other industrial inputs or maintenance and idleness of machines and f) the flexibility of production processes, product innovations, among others, are not motivators of 4.0 projects.

It is important to mention that over the last decades, as well as Portugal, Brazil has developed innovation policies oriented to different sectors and technologies such as information technology, telecommunications, fine chemistry, aerospace, nuclear energy, biomass, agriculture, capital goods, etc. However, it is emphasized that a large part of these efforts has not produced practical results in terms of increased international competitiveness.

As such, even considering in Portugal the improvement of indicators, after the 2008 crisis, as a small economy, the support and "big push" from the EU was fundamental to allow its permanence in the euro zone and for the formation of an innovative industrial ecosystem. In the other hand, in Brazil the lack of cohesion in industrial policies in recent years may be a limit to the advancement of Industry 4.0. It should not be overlooked that studies on innovation highlight that in both countries the lack of digital skills is one of the factors contributing to the delay in the development of two other key areas for digital transformation: electronic services and the adoption of new technologies.

For the purpose of understanding these changes and their implications, in the theoretical field, the relevance of the study lies in two aspects: first, in relation to the production of research (basic and applied); second, in relation to the flow and intersect oral diffusion of industry 4.0. The purpose of the study is to understand these changes and the reflections they have raised, performing a comparative analysis focused on the interweaving of industrial policy with trade and innovation policies in the period from 2008 to 2018 in Brazil and

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Portugal. Accordingly, the following research questions are addressed in this paper: What are the limits and impacts of industrial, trade and innovation policies from an industry 4.0 perspective in both countries?

The structure of the article is organized as follows. Section 2 presents the conceptual framework and the analytical structure. Section 3 describes the methodology used, since it is based on the access to databases in order to evaluate innovation policy from its industrial and trade policies settings. The comparative analysis of the results and its discussion are carried out in Sections 4 and 5 in view of the industrial, trade and innovation policies adopted by the two countries in the new context of industry 4.0. Finally, Section 6 summarizes the main conclusions drawn from the investigation and provides some clues for further research.

Conceptual framework

The role and multiple faces of industrial policies: The strategic coordination of industrial policy is perceived as an institutionally structured process [5] that is, a process using different policies and organizational models. In the discussion of the "new industrial policy" what fundamentally matters is which type of activities adds more value. In this context, contemporary industrial policies are increasingly diverse and complex, focusing on a broad set of objectives that go far beyond conventional industrial development and simple structural transformation (manufacturing instead of agriculture; services instead of manufacturing), including the integration in global value chains (GVCs), the development of a knowledge economy, the construction of sectors linked to sustainable development goals and the competitive positioning within the new industrial revolution. Differently from the past, it should be noted that industrial policy in recent decades has been more clearly associated with the development of horizontal relations in functions of the economic system among innovation agents, including companies, universities and the government, with the support of business, finance and technological initiatives, as well the creation of companies and promoting competitiveness through the innovation ecosystem [6-8].

In this direction, the debate around the role of industrial policies went beyond the rationality of failure, be it of the markets, governments or systems [9-15] combining the structuralize ontology of micro, meso and macro with the functional ontology of the principles of evolutionary change. As described by Chang (2011), industrial policy can be seen as an "institutionally structured process", based on three determining issues: structural interdependencies, institution building and policy alignment, and conflict management.

Several studies and models on the multiple faces of industrial policies [16] describe the nature of industrial policy as horizontal through different policy instruments of a national government (and eventually sub-regional governments) as well as their potential interactions that link the policy instruments implemented by different institutions in various domains. This also means understanding the distribution of different instruments and resources through which institutions operate in the same policy area and, above all, in the same direction. In addition, the presence of interactions within the global policy mix suggests how countries can take different measures and coordinates policy instruments, either to have a combined effect on the same target or to manage potential trade-offs between different objectives.

Implications of changes in trade policy: An extensive literature has investigated many aspects of structural changes in the composition of international trade since the 1990s [17,18]. The first implication is the "servicification", that is, services are increasingly more representative in trade: in fact, between 1995 and 2014, exports of services rose from more than one trillion US dollars to about five trillion US dollars [19]. It is worth reminding that primary commodity dominated world trade up to the early 1960s, although they remained important, the following decades of the 20th witnessed the role of manufacturing goods as its driver. The second change has been the globalization of the value of companies or production through GVCs (following decades of increasing foreign direct investment), where intermediate rather than final goods and services are exchanged internationally. A third change is the fact that the market of goods and services is expanding in its digital form, and as an example of this weight: according to Jacks DS and Novy D [20] services account for about 20% of global trade and about 50% of services traded worldwide are digital.

Subsequent to the rise of China in the global economy, even with the US maintaining its leading position in the investment stock, credit, energy and commodity markets, and more importantly still, the dominance of the US dollar in international payments, there has been a rising conflict with the US, at first sight, due to the imbalance in bilateral trade, with a view for increasing the competitiveness of high-tech companies and foreign investment from China. The Covid-19 pandemic that began in 2020 and the associated economic crisis developed when this process of conflict was in full swing, and significantly exacerbated in terms that it is difficult to predict the final result, even if in June 2020 China and the US reaffirmed the "phase one" agreement signed by the two countries as a way found to curb the negative effects that the succession of tariff hikes was having on the economies and financial markets [21,22]. In 2021, the change to a new Administration in the US put a different political setting for these issues, eventually more cooperative (Krueger, 2021), however, much of this conflict with China, particularly in the field of high technology, will likely remain.

Different empirical findings suggest a strong positive link between trade and growth [23] namely based on the enlargement of the market and consequent intensification of competition, which has led governments to invest in the formation of economic integration blocks. It is widely relevant in political and academic debates that integration agreements and other forms of trade policy liberalization contribute to economic growth and the development of nations. As the European case shows, the extra-economic impacts of this integration are also relevant (when the Treaty of Rome in 1957 advanced to the European Economic Community, Europe had behind it, the fact that it was the focus of the outbreak of two world wars in about a quarter of a century). Thus, these agreements, according to the classical teachings, based on common interests, have proliferated not only bringing more peace and cooperation like in Europe but also changing economic structures and income distribution in the countries that are comprised within them. It is important to remind, that economic integration agreements are not however linear processes, and in a variety of contexts, they create “winners” and “losers” as showed in a recent work by Hashai N and Buckley PJ [24].

The role of innovation policy from the perspective of industry 4.0: The idea of digitalizing the industry provides a window of opportunity from the new paradigm in which the industry 4.0 is sustained. In this context, the concept of "policy mix" has become popular among the academic and innovation policy communities, as increasingly complex innovation environments require a more holistic approach to governance [25,26] propose to define the concept of "policy mix" as "the set of interactive policy instruments of a country dealing with R&D and innovation. In general, empirical studies prefer to discuss the concept in normative terms and identify the desirable characteristics of the policy mix among "different subjective criteria" [27].

Kergroach S [25] highlights that industrial policy and technological updating is a multidimensional process related to public policy interventions to improve the technological and productive capacity of a country. Such a policy takes different forms and mobilizes different instruments in different policy combinations. As a consequence of the previous analysis, these combinations and their density are defined by structural characteristics, in terms of national absorption capacity and comparative advantages of the national innovation system. Our understanding is that some governments also focus efforts on strengthening industry links with the knowledge base, constitute spin-offs, promote the internationalization of universities and research centers with exchanges in areas where there is strong R&D, strengthen and enlarge the supply of skills, and encourage international mobility of talent. In other countries, programs to support international cooperation could be equally relevant as they facilitate knowledge transfer and help to pool resources. However, interactions between policy areas are less noticeable when it comes to achieving industrial upgrading, and if industrial and cluster programs remain the backbone of public policy.

Given its importance, the industry 4.0 phenomenon’s was mentioned for the first time in 2011 in Germany as a proposal for the development of

a new concept of its economic policy based on high-tech strategies. The concept launched the 4IR, based on technologies that include cyber-physical systems; the Internet of Things (IoT) and the Internet of Services (IoS) [28] also address such Internet-based technology that enables continuous interaction and information exchange not only between humans (C2C), and humans and machines (C2M), but also between machines themselves (M2M). This communication interaction influences the establishment of knowledge management 4.0.

When considering the technological level of developing countries, it is important to consider the creation of competitive advantages, the financial and structural limitations of the technological profile of industry, economic integration and industrial policy). In the theoretical discussion about the industry 4.0 perspective, research referenced by experts focuses on the practices and innovations brought by the industry 4.0 concept, but also the expected advantages. Other specialized studies are focused on analyzing the evolution of the industry 4.0 concept in some industrial segments [29].

Methodology

In this section, the research methodology is described. Thus, as for the objectives, the research is characterized as a descriptive study with the purpose of observing, recording and analyzing the phenomena or technical systems, without deepening the merit of the contents [30]. As for the nature, according to Bryman A and Cramer D [31] the research is qualitative due to the absence of metric numbers, classified and analyzed, not applying statistical techniques. The study carried out was of an applied nature, being designed from documental research through the use of secondary data.

The criteria for the selection of the period used in the study was based on the conditions and impacts triggered by world financial crisis that broke out in 2007, followed by the debt crisis and recovery of the Portuguese economy, and the fiscal crisis in Brazil during the 2010s, with the reference for analysis being the period 2008-2018. Necessarily, as it focused on the study of literature, the intention to analyze the mix of public policies, particularly industrial, trade and innovation policies, as well as their recent transformations, required considering a period in which such a process would make sense.

Thus, to build the results, the main databases accessed were for Portugal, the National Institute of Statistics (INE), and the DGEEC/ME-MCTES- "Survey on the National Scientific and Technological Potential" and for Brazil, the Institute of Applied Economic Research - IPEA, and the Coordination of Indicators and Information (COIND) - CGGI/DGE/SEXEC- Ministry of Science, Technology, Innovation and Communications (MCTIC). Among others, we also obtained statistical information from the Bank of Portugal and Ministry of Economy in Portugal, and from the Brazilian Geographic and Economic Institute - IBGE in Brazil.

Results

Portugal

According to PORDATA [32] in 2018, there were 68.214 companies in the manufacturing industry of Portugal against 78,431 in 2003 and 81.387 in 2008, made up mostly of food, clothing and metal products industries. So, from the sectorial point of view, such data shows a significant drop in the number of manufacturing firms between 2008 and 2018 (-16.18%). As far as growth is concerned, it must be noted that after a deep recession in the beginning of the 2010s, Portugal began to recover in 2014, and the process was accelerated by the end of the decade. According to INE [33] annual data, after a rise of 3.5% in 2017 and 2.4% in 2018, national GDP grew 2.2% in 2019, a slowdown that was also observed in almost all Europe.

It is important to highlight that the Portuguese economy presents a profile of industrial specialization based on added value and employment, in activities of low or medium technological intensity, particularly concentrated in the North and Center regions. In fact, high-tech industries represent no more than 4% of gross added value of the sector. The productive structure shows a high concentration in the services sector, of which only about 40% is knowledge intensive, although some industries show relative levels of technological sophistication, as is the case of the most advanced segments of textiles and footwear. It should be noted that the manufacturing industry benefits from national scientific specialization in several areas, such as Composite Materials Science, Biomaterials Science, and Chemical, Manufacturing and Industrial Engineering. It is noteworthy that the existence of a business structure highly composed by SMEs and with little collaborative and associative activity, is still very much focused on non-tradable production, i.e., for the domestic market.

In the international market analysis, Portugal expanded exports by 3.6% in 2019. In the same period, imports increased 6.6%, which led to a worsening of the trade deficit (fob-cif) of 16.2%. In value, Portugal exported 59.9 billion Euros in 2019 (ranked 49th in the world in INE, 2020) and imported 80.3 billion Euros, which translates into a coverage rate of 74.6%, the lowest since 2011 (71.9%). In spite of this deficit in the trade of goods, and contrary to what happened in most of previous decades since the 1970s, the current account had a surplus between 2013 and 2019, allowing an external link with less restraint (and we need to bear in mind that, since 1999, much of the Portuguese transactions is made through its own currency, the euro). Anyway, Portuguese companies still have low export intensity. In fact, after entering the European Union, the share of Portuguese exports of goods and services in GDP remained around 30% or even less up to the end of the first decade of 21st century. This weak participation reflected an insufficient pace of insertion in the mechanisms of the European Single Market and in the globalization process, as well as difficulties in product specialization and market diversification, evidencing a greater concentration of non-tradable activities. Although the ratio of exports to GDP substantially increased after 2010, it is necessary however to take into account the exceptionality of this period, owing to the profound impacts of the financial crisis and its aftermath (the European sovereign debt crisis that followed); as the domestic market had then significant limits, there is not yet consistent proof of the sustainability of a great scale of exports endogenous to the Portuguese economy. Furthermore, even if progress has been made in its internationalization, this an aspect broadly recognized as one of its weaknesses, given the growth prospects of international markets since the enlargements of 2004 and 2007, insofar as some member states of Eastern Europe of close GDP per capita clearly demonstrated a better performance.

In this context, during the last decade, an industrial policy mix should be added. It incorporated into Portuguese economy the guidelines of the Lisbon Strategy, and more recently of the Europe 2020 Strategy, establishing a favorable framework to the consolidation and qualitative reinforcement of its National Research and Innovation System. This policy created conditions for a change in the technological intensity and knowledge profile of the economy, which can lead to an increase in the investment around activities with greater added value potential, upgrading the country's positioning in the international market. Since the first decade of the 21st century, Portugal has maintained its focus on accelerating R&D effort, which has allowed a significant enlargement in its scientific and technological base, with an average annual rate of 8% in terms of human and financial resources, in particular expanding R&D expenditure as a percentage of GDP and the number of graduates from higher education in scientific and technological areas.

In the period under review (2008-2018), the composition of the public sector in Portugal has also substantially changed, with the consolidation of universities, research centers and institutes, making them more dynamic. In the opposite direction, the marginal weight of the State sector is noteworthy, with a significant drop in the weight of State Laboratories performing R&D activities. According to Figure 1, higher education increased its share from 0.50% in 2008 to 0.56% in 2018, while direct State spending went from 0.11% in 2008 to 0.07% in 2018. R&D spending in percentage of GDP in 2017 reached the average in 2013 (1.33%), while in 2015 the Figure reached the lowest level of 1.24% of GDP, in 2018 it represented 1.37% of GDP and the current government (elected in October 2019) set a target of 3% for 2030.

As regards innovation, it must be emphasized that despite all the national effort made in R&D the associated results do not yet reflect the process of transformation observed over the past decades. As far as the patenting effort is concerned, the data are still very low in relation to the European average,

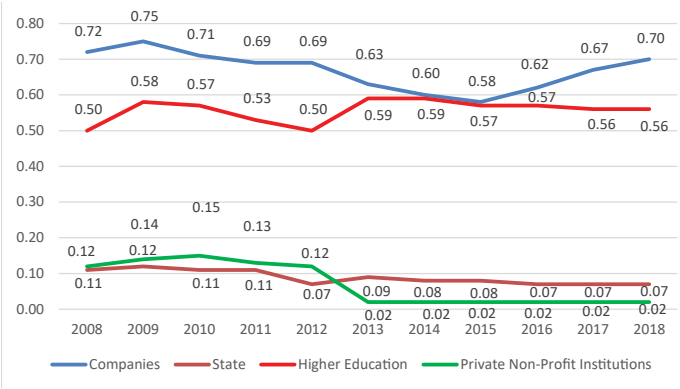

Figure 1. National expenditure on science and technology (S&T) in relation to (GDP), by institutional sector, 2008-2018 Portugal. (Source: Own elaboration from PORDATA/ INE data).

either as a result of the culture of the organizations, the characterization of 96% of SMEs in the country's business structure, the level of costs and financing, as well as the uncertainty and domestic competitiveness profile of the companies. Indeed, in terms of patent applications, in 2008, according to data from INE (2018), the number of applications for protection of inventions originated in Portugal filed at the European Patent Office (EPO) was 127. In turn, in 2017 there were about 272 applications. However, even with an increase in the period, the number of applications is still much lower than other European countries such as Sweden, which in 2017 filed 8.838 patent applications at EPO.

However, the dynamism of the R&D sector and the increase in companies' capacity for innovation has had a positive influence on the technological balance of payments with a contribution from the sale of R&D services abroad and a reduction in technology imports, given the greater capacity to produce technology. In relation to the European Union average, but corresponding to its type of international specialization, Portugal presents a higher percentage of companies with innovation in services and a lower percentage of companies with innovation in goods and the introduction of new products in the market. The most common innovation activities in the country are the acquisition of machinery, equipment and software, training for innovation activities and carrying out R&D activities inside the country. A smaller number of companies are identified with external acquisition of R&D and other external knowledge (either in Portugal or in the EU).

Since the end of the 1990s up to the middle of the 2010s the performance of the Portuguese economy was unfavorable in terms of growth and real convergence with the EU (stagnation, IMF/EC/ECB bailout of 2011, divergence with European partners, a growth rate much lower than some Eastern new member states, etcetera). The improvement of macroeconomic context after 2015 led to more ambitious goals by the end of the decade. So, according to data from the Portugal (2019), the Industry 4.0 Program is a guideline for achieving the goal of a decade of convergence of Portugal with the European Union, which was inscribed in the National Strategy for the Horizon 2030. The Industry 4.0 Program is a lever of the National Strategy for 2030, contributing directly to 2 of the 3 crosscutting priority objectives after 2020. In particular, the proposal for the National Strategy Portugal 2030 (i.e. Post 2020), announced by the Portuguese Government, had as main objective to achieve "a decade of sustained convergence with the European Union," involving more than 20,000 companies operating in Portugal, train and retrain of more than 200.000 workers in digital skills, and the finance of more than 350 transformation projects. According to the National Innovation Agency, 74 projects have been identified within the reach of this Program (PT2020), corresponding to an investment of 125.8 million euros. In the PT2020 a new support measure was introduced, created specifically to stimulate industry 4.0, called “Vale Indústria 4.0". The projects of Industry 4.0 include, for the most part, the development of solutions for digitalization, data processing, simulation systems, artificial vision integration and intelligent sensing, biometric systems, production process monitoring systems, security decision support systems in computer systems, the use of artificial intelligence in industrial robotics, the development of robotized or automated solutions or intelligent energy efficiency management solutions.

Brazil

After a serious crisis in the triennium 2014-2016, the Brazilian industry has been able to survive in a path that has been slow and discontinuous. The dynamism of the industrial production in Brazil in 2019 was negative, retreating (-1.1%), after two consecutive years of growth as 2017, which showed an increase of 2.5%, and 1.0% in 2018. In this context, what marked the transformation of industry's trajectory throughout 2019 was the oscillation between positive and negative variations, with the second half of the year being a period more favorable [34].

Even though the expenses in S&T have substantially grown in this first decade of the 21st century, considering the approval of the regulation of the National Fund for Scientific and Technological Development (FNDCT, Law No. 11.540/07), a norm that allowed the execution of all the resources of 16 sector funds in 2010 and the Good Law (11.196/05), Innovation (10.973/04) and the Law of Biosafety (11,105/05), the percentage reached 1.2% of the GDP while, in the previous years, this value was not more than 0.9%. There is a strong state activism, but with a very low result and mainly a low private participation, according to Chart 2. Even though R&D spending is only a part of what is done in innovation, there is the impact of the recession and the fiscal crisis in the fall of federal R&D spending. The private share is estimated considering the fall in industry share of GDP and based on the hypothesis that R&D spending in relation to net sales revenue has remained constant since the last Innovation Research in 2017 (IBGE, 2020). This is a reasonable hypothesis, because this indicator has remained constant in recent years, although the crisis may have reduced this type of expenditure.

According to a report by NCI (2016), Brazil's scientific production expanded about 30% between 2013 and 2018, representing twice the world average, which reached about 15%. This condition makes the country the 13th science producer in the world in number of published works, even if the economic crisis began in 2014, and the significant budget cuts in the Ministry of Science, Technology, Innovation and Communications, which resources have almost halved since 2014. Data from the EPO (2017) show that in a decade, Brazil had a jump in the number of scientific articles published with an increase of 69.4%. In 2008, there were 35.490 publications and in 2018 their number reached 60.148 published articles. Brazil in the same year was the 11th in the ranking of scientific publications, ahead of Canada, Spain, Australia and Iran. According to the World Intellectual Property Indicators (2019) report from WIPO (World Intellectual Property Organization), in 2018 there were 24.857 patent applications in Brazil, a 3.1% retraction compared to 2017. On the other hand, 3.3 million applications were filed worldwide, representing a 5.2% increase compared to 2017. Previously, only in 2009 there was a decline, due to the global financial crisis, but between 2009 and 2013, there was an expansion in patent deposits in Brazil, and a decrease in 2014. The number of patents granted has been increasing, since in 2018 it was 82.9% higher, compared to 2017, from 5.450 to 9.966. According to information from the Global Intellectual Property Center, Brazil is the 31st on the list of patents granted by the USPTO, the American Office of Trademarks and Patents, although it publishes many scientific articles, a position lower than Latin American countries such as Mexico, Chile, Peru. Figure 2 shows how R&D spending has been systematically deteriorating as a percentage of GDP, both in the public and private sectors, respectively since 2013 and 2015.

In Brazil, the industry 4.0 has been highlighted in the context of industrial policy by the Brazilian Chamber of Industry through the Most Productive Brazil, but with low results in indicators of innovation and low business protagonism. Indeed, research data from the National Confederation of Industry - NCI (2017) indicate that in the sectors of capital goods, only 1.6% of companies consider themselves on stage 4.0 today and 20.5% on stage 3.0. Thus, 22% of the companies in Brazil are on the stage of the so-called "integrated automation" or "automation 4.0", while the rest, almost 80%, are still in rigid production or lean production. According to data from the Brazilian Machinery Industry Association, it is estimated that the average age of industrial equipment in Brazil is 17 years, which is very high comparing to international patterns. On

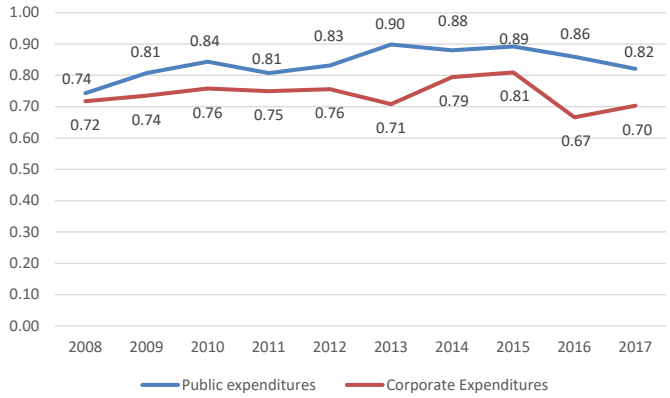

Figure 2. National Science and Technology (S&T) expenditure in relation to (GDP), by institutional sector, 2008-2017 Brazil. (Source: Own elaboration based on data from the Coordination of Indicators and Information (COIND) - Ministry of Science, Technology, Innovation and Communications).

the other hand, the number of patent applications of industry technologies 4.0 in Brazil has increased 11 times over the last decade comparing with the total number of deposits, according to the study of the National Confederation of Industry. In fact, in 2008, 1,202 patents were deposited for inventions related to industry 4.0 technologies, which represented 5% of the total of 23.170 requests made that year. A decade later, in 2017, 14.634 patents related to this industry were deposited, which represented 57% of the total of 25.658 requests.

In Portugal, in the last ten years, R&D spending has been stable. In 2008 there was a big drop, both in the product and expenditure, but from then on, in practically all OECD countries; R&D expenditure accelerates at a rate higher than the GDP. The big difference between Brazil and Portugal and countries such as Korea and China is the volume of expenditure on S&T made mainly by private initiative. While in OECD countries, companies invest 1.3% of GDP, in Korea 2.6% and in China 1.2%, Brazil's private initiative in 2017 reached 0.70 and Portugal 0.67. In Portugal, the State does not have the participation it has in Brazil; however investment by higher education, basically public institutions, must be pointed out, as shown in Figure 3.

Discussion

In line with industrial policy models, the most frequent measures in the policy mix in Portugal have been associated and are related to investment incentives in the form of tax or financial support through loans and the concession of resources to target sectors, performance requirements, special economic zones (including clusters, incubators and science and technology parks), investment facilitation, target investors and screening and monitoring procedures to startups.

In general, the trend of declining manufacturing in Portugal cannot be dissociated from the difficulties that the Portuguese economy underwent after the implementation of the single currency, the exposure to competition that resulted from China's accession to WTO and the expansion of the EU to the East, processes highly characteristic of the turn of the century. Just after EC membership, Portugal benefited from transition trade regimes and from cohesion funds in order to be prepared for a more competitive market, however not always these resources were well applied, and the country lost market share in manufacturing. In addition, a privatization program, and the deregulation of financial activities within the context of the European Single Market had proceeded mostly in the 1990s. In the early 2000s, the economic policy followed in Portugal, as well as in other euro zone countries, has been a kind of industrial policy of structural change driven by a real exchange rate appreciation and a substantial fall in real interest rates, which led many firms to turn to non-tradable goods sector, weakening the development of productive activities with higher added value due to a lack in price competitiveness. The crisis of the model, triggered by the financial collapse of 2008 at a world scale, was evident with the bailout of 2011 that led to three years of an IMF's program (also with the European Commission and the European Central Bank). However, the manufacturing decline has been minimized during the period insofar the weight of high-tech industries was increased and that the degree of complexity of the pattern of specialization of Portuguese economy has advanced positively. In fact, the EU's structural funds have benefited the scientific and technological system, as well as innovation and later the process also contributed to the internationalization of the business sector [35]. Therefore, from the structural and competitiveness points of view, the state of the economy was complex.

The recovery in Portugal from 2015 onwards has been to a large extent packed with the reduction of macroeconomic imbalances. The structural reforms introduced have led to a rebalancing of the economy, with exports rising steadily. Moreover, education indicators have begun to signal a number of more qualified human resources, a business base with more R&D activities, and a greater diversity of public policies and sources of financing and support for innovation with strong governance of national entities. However, the analysis of industrial policies in the period is also characterized by an unsatisfactory pace of structural change in the Portuguese economy insofar the leeway for effective policies is narrow, among other factors, due to high degree of indebtness (public and private). A first aspect to consider is the macroeconomic context evidenced by a low level of public investment in comparison with previous decades, which would be important if linked to a policy mix, more precisely to policies aimed at promoting the expansion of more sophisticated industries (the most important contribution for the recovery of the late 2010s was tourism, which cannot be included in that category). Another aspect would be the raising of the level of education, through professional training of the workforce because the weight of low skilled workers remained high hindering the potential for rapid and large structural change.

An analysis of the Brazilian scenario shows that, as a country of late industrialization, Brazil has not migrated to the export-oriented industrialization model. Since the 1930s to this day, the import substitution policy remains an important pillar of Brazilian industrial policy. In this context, the industrial policy still demands projects capable of mobilizing industrial segments or changing the industrial structure, from the point of view of orienting it to new segments. In part, because the most recent industrial policies, such as the Industrial, Technological and Foreign Trade Policy, the Brazil Bigger Productive Development Policy, among others, were shortened by the lack of alignment among federal agencies, in addition to the international context of the 2008 crisis and the political immbroglio that culminated in the impeachment of President Dilma Rousseff in 2016 and the election of a right-wing party allied with a neoliberal agenda in 2018. Even if it happened in different contexts and at different times, the policies in the last ten years ended up collapsing, but they were important even though they had minimal results. Since 2004, three different versions of industrial policy have been implemented. The first was the Industrial, Technological and Foreign Trade Policy (ITFTP) which consisted of a federal government action plan aimed at increasing the efficiency of the production structure and innovation capacity of Brazilian companies, as well as the expansion of exports. Although ITFTP's design and its focus on

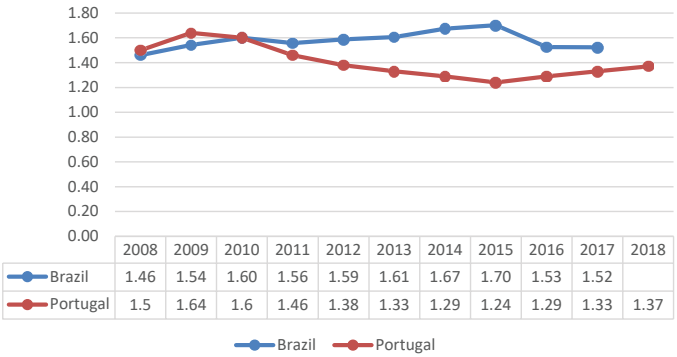

Figure 3. National S&T expenditure (%) relative to (GDP), 2008-2017. (Sources: Own elaboration based on INE-Annual National Accounts/PORDATA/Coordination of Indicators and Information (COIND)-Ministry of Science, Technology, Innovations and Communications).

fostering innovation are in line with the economic development literature, which emphasizes the important role of innovation in long-term growth, this policy has been criticized for its lack of clarity and objectives regarding the most labor-intensive industrial sectors, such as footwear, textile and apparel, wood and furniture, etc., which are important employers in the Brazilian labor market. This policy had a low elasticity of implementation in these sectors, but its great merit was the development of clusters and productive arrangements as a policy implemented by federative entities throughout the country, but with effective evaluation of public policy.

In 2008, the government decided to launch a second broader industrial policy, the Productive Development Policy (PDP), which was praised precisely for including several sectors. In our understanding, unlike the ITFTP, the PDP aimed not only to promote more technology intensive sectors, but also to consolidate Brazil's leadership in sectors in which the country already enjoyed comparative advantages, the setting of goals by the PDP was a move in the right direction, although these goals were mostly aggregate goals, which did not allow for the monitoring of the companies that were encouraged, as was the case in South Korea with "reciprocity mechanisms", defined as a set of goals (exports, productivity growth, R&D spending, etc.).

The third version of the industrial policy adopted by Brazil was the Brazil Bigger Plan, in August 2011, which was influenced by a situation where the GDP of the manufacturing industry was stagnant because the growth of industrial employment in mid-2011-2014 became negative in several labor-intensive sectors, the industry continued to lose space in the list of exports from Brazil and industrial imports, increased its market share in apparent consumption. In this context, the Brazil Bigger Plan was an attempt to reconcile long-term structural measures with short-term measures to halt the loss of competitiveness of Brazilian industry in the face of an adverse international scenario, characterized by excess supply of manufactured products; excess demand for commodities due to China's growth and a positive macroeconomic scenario for the Brazilian economy, which increased the attraction of foreign capital and increased the value of the real, deteriorating the competitiveness of Brazilian manufacturing industry due to its characteristics. This process led Brazil to a greater international insertion (through the flow of commodities) without taking the required measures to improve business competitiveness in industry.

One fact that stands out is that in attracting foreign direct investment (FDI) to technology intensive sectors, Brazil has used an industrial policy focused on local content requirements, strengthened by the governments of Presidents Lula da Silva and Dilma Rousseff. As such, foreign multinationals were able to avoid import tariffs on components and final goods and received tax credit from federal and state governments when producing and supplying domestically. Such a requirement for local content in Brazil, with detailed and growing incentives for domestic production, did not take into account industrial requirements for effectively upgrading production, global industry structure or suitability for Brazil's existing industrial or skills base. The local content rule applied to the oil and gas sector was not unprecedented in Brazil's industrial policy. In 1991, the country also adopted a similar policy for information technology, which forced the public administration to give preference to Brazilian products in the bids of the industry. The rule lasted until 2001. Brazil continues to adopt this policy on the automotive sector, but that doesn't demand a minimum perceptual obligation. The government gives tax incentives to the automakers that realize part of the productive processes in the country and invest on R&D. Considering the question of spillovers, in some conditions; it has led to the strengthening of the industrial park and the increase of productivity, with positive impact in several sectors. Other effects were the creation of jobs and contribution to the balance of foreign trade. But, to a good extent, it reinforced the isolation of the national industry from external competition, reducing productivity and increasing inefficiency, in addition to restricting access to new technologies. Significantly, it was announced in 2021 that Ford and Mercedes-Benz would close parts of their plants in Brazil. Moreover, this policy option has not mitigated the effect of the “Brazilian costs”, i.e., high taxation and poor transportation infrastructure, red tape, low product quality, explaining why the exports of Brazilian industrial companies and the Brazilian affiliates of multinationals are uncompetitive.

The adverse effects of macroeconomic policy on industry are historically known, either through the use of the basic interest rate as an instrument to control inflation under a target system that over the years has inhibited investments in terms of the cost of capital, making the financing of production and marketing even more expensive, although from 2018 onwards cuts in the basic interest rate promoted by the Central Bank reached the lowest levels in the country. In addition, this policy implied high exchange volatility under the floating exchange rate regime that prevails in Brazil, including periods of overvaluation of the real, contrary to ITFTP's own efforts to promote exports. It is not surprising that primary and manufactured commodities based on natural resources have remained, and even increasingly became dominant in Brazilian exports, whose price is also more aligned with international prices rather than dependent on exchange rates. Finally, the obstacles of the taxation policy were also bottlenecking for industrial policy (as a federal country, Brazil as different taxes at the central and state level what can be complex to manage).

Conclusion

The objective of this paper was to identify the new contexts in which industrial, trade and innovation policies are developed from the perspective of industry 4.0, based on data from Brazil and Portugal during the period 2008-2018. The following research questions were addressed: What are the limits and impacts of industrial, trade and innovation policies from an industry 4.0 perspective in these countries?

Amidst the current discussion of industrial reconversion, the results reveal that Brazil continues to be specialized in the production and trade of commodities, and has a limited knowledge base, insofar, on average, invests little and much less than advanced countries in R&D and innovation. Consequently, and in spite of its big scale of production and potential, in particular the abundance of natural resources than can be downstream transformed, its participation in global value chains is in general poor and unable to significantly activate the learning processes. On its turn, Portugal, within the European Union, even though it has advanced in the production of medium technology products and has access to R&D support funds and other incentive policies from EU, as an open economy, with a structure of more than 95% of small businesses, has still infrastructure and linkage problems (for example, in applying science to productive purposes) that limit the competitiveness performance of its industries.

The industrial and trade policies in both countries have been impacted by the crises that occurred since 2008, although the pandemic crisis (COVID-19 due to SARS-2) is not yet clear in many of its effects in the moment we write. On the one hand, there are limits to technological overflows and to an increase in the participation of both countries in global trade outside the logic of economic integration or insertion into blocks and free trade agreements. On the other hand, the health and economic crisis derived from the Covid-19 pandemic exposed their external dependence on essential goods, such as protective equipment, respirators, and gloves, which needed to be imported. In the process of production and distribution of vaccines that followed, both countries also showed fragilities and dependence. In this context, it will be useful to rethink the current model of extensive dependence on global value chains, not excluding the internalization of the production of strategic items, or at least some of them. Indeed, as increasingly emphasized for the post-pandemic era on global positioning, long supply chains, dependent on foreign and distant suppliers to deliver inputs and low stocks of strategic goods will possibly give way to shorter ones. It is obvious that increasing automation in the context of industry 4.0 can contribute in that sense. So, there is a discussion about how to create these new value chains, with the least possible costs and seeking to maintain the essential of the supply of such goods and their inputs. It will not be easy to find a solution, but for example the hypothesis of an evolution towards a more confrontational world in political and security terms, one of the global trends of the last years, will likely put some brakes to avoid excessive foreign dependence on such strategic goods. This is not our central problem in this paper but countries like Brazil and Portugal must be prepared for such scenarios.

As regards the research question, about the limits and impacts of industrial, trade and innovation policies from the perspective of industry 4.0, it is necessary to redesign in the medium-term alternative supply chains, which infrastructure must link to other countries. However, in this context, priorities must be considered, particularly as far as strategic goods are concerned, as well as forward-looking interventions, allowing the building and expanding of innovation ecosystems, encouraging open innovation efforts, increasing investment in education, R&D, credit facilities, and open networks to attract talent and promote resilient ecosystems in programs that ease labor displacement and flexibility, including job matching and retraining.

As regards about the most frequent measures of the mix of trade, industrial and innovation policies that were used in the two countries, it must be highlighted that the innovation policies with success are related to externalities, such as Portugal within the European Union or to industrial policies that attract companies to sectors where the technological strategies comply with areas of comparative advantage of the country. The data presented show that since Portugal's membership of the European Community, innovation policy is linked to the funds provided by the European Union Support Frameworks that follow the European guidelines in the field [36]. Among the sectors with comparative advantage, there is predominance of footwear and textile sectors that have undergone technological revitalization in the 2010s, well visible after 2015 with the improvement of the confidence levels in the economy following domestic macroeconomic stabilization. Beyond the traditional case of tourism and some agricultural products like wine, there are opportunities for development policies in higher added value chains in the area of maritime products and services like healthcare [37]. Anyway, one of the most important policy challenges of Portugal is to put traditional industrial sectors, where presently lies much of its comparative advantages, in the way towards 4IR. In the case of Brazil, the characteristics that allow the country to be ahead of sustainability agenda due to the fact that it has the largest biodiversity in the world are still limited due to the fragile innovation system.

The process of digital transformation, in particular, which had already been boosted in the industrial procedures of developed countries, can be accelerated in post-pandemic times in Brazil and Portugal. Furthermore, to deepen international cooperation networks will be crucial for this process to take place in developing countries. In the case of Portugal there is a path towards policies of launching the hydrogen cluster, the development of sustainable bio economy, with the focus on a greater value of the forest biomass, and the sustainable development of some strategic mineral and maritime resources. In general, both countries, even Brazil in spite of its big size, particularly in these fields, are not in a position of "agenda setter" and must adapt their programs to changes on the ground.

The results achieved in this research did not point to definitive conclusions, requiring the need for other lines of research, and taking into account the academic and political ongoing debates, originating policies that are directed to a mix of policies, not only those that we have analyzed in-depth, but that also including education, worker training, among others, aiming at the strengthening of industrial structure that is at the base of each economy, while at the same time continuing investigations on the market developments leading to the constant adaptation of the industrial process to new technologies in order to be externally competitive.

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