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DOSSIER: INDUSTRY 4.0

Industry 4.0 and technological unemployment in Brazilian manufacturing: Policy proposals

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Abstract

The digital transition in the first decades of the 21st century has hit Brazilian industry in the midst of a long-term weakening process, in which the progressive loss of competitiveness of the industrial system is added to the loss of participation of technology-intensive sectors in the national manufacturing production. In this context of specialization in sectors and tasks of low complexity, the Brazilian industry will suffer severely from the effects of the new wave of automation throughout the current decade. The article seeks to visualize possible scenarios, discuss the probable impacts of technological unemployment on Brazilian industry, and stimulate debate on policies for dealing with the problem.

Keywords: Industrial Organization; Technological Innovation; Brazilian Industry; Unemployment.

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Indústria 4.0 e desemprego tecnológico na manufatura brasileira: Propostas de políticas

Resumo

A transição digital nas primeiras décadas do século XXI atinge a indústria brasileira em meio a um processo de fragilização de longo prazo, no qual a progressiva perda de competitividade do sistema industrial se soma à perda de participação dos setores intensivos em tecnologia na produção manufatureira nacional. Nesse contexto de especialização em setores e tarefas de baixa complexidade, a indústria brasileira deverá sofrer severamente com os efeitos da nova onda de automação ao longo da década atual. O artigo busca visualizar possíveis cenários, discutir os prováveis impactos do desemprego tecnológico na indústria brasileira e estimular o debate sobre políticas para o enfrentamento do problema.

Palavras-chave: Organização industrial; Inovação tecnológica; Indústria brasileira; Desemprego.

Industria 4.0 y desempleo tecnológico en la industria manufacturera brasileña: Propuestas de políticas

Resumen

La transición digital en las primeras décadas del siglo XXI golpea a la industria brasileña en medio de un proceso de debilitamiento de largo plazo, en el que la progresiva pérdida de competitividad del sistema industrial se suma a la pérdida de participación de los sectores intensivos en tecnología en la producción manufacturera nacional. En este contexto de especialización en sectores y tareas de baja complejidad, la industria brasileña sufrirá gravemente los efectos de la nueva ola de automatización a lo largo de la presente década. El artículo pretende visualizar los posibles escenarios, discutir los probables impactos del desempleo tecnológico en la industria brasileña y estimular el debate sobre las políticas para enfrentar el problema.

Palabras clave: Organización industrial; Innovación tecnológica; Industria brasileña; Desempleo.

Industrie 4.0 et chômage technologique dans l'industrie manufacturière brésilienne: Propositions de politiques

Résumé

La transition numérique des premières décennies du XXI^e siècle frappe l'industrie brésilienne au milieu d'un processus d'affaiblissement à long terme, dans lequel la perte progressive de compétitivité du système industriel s'ajoute à la perte de participation des secteurs à forte intensité technologique dans la production manufacturière nationale. Dans ce contexte de spécialisation dans des secteurs et des tâches de faible complexité, l'industrie brésilienne souffrira sévèrement des effets de la nouvelle vague d'automatisation tout au long de la décennie actuelle. L'article cherche à visualiser les scénarios possibles, à discuter des impacts probables du chômage technologique sur l'industrie brésilienne et à stimuler le débat sur les politiques à adopter pour faire face à ce problème.

Mots clés: Organisation industrielle; Innovation technologique; Industrie brésilienne; Chômage.

Introduction

The digital transition that gained momentum in the second decade of the 21st century has hit Brazilian industry in the midst of a persistent weakening process - which had been taking place since the end of the 20th century - in which the progressive loss of competitiveness of the industrial system has been reinforced by the loss of participation of technology-intensive sectors in the national manufacturing production (Diegues, 2021).

Among the various expected consequences of the diffusion of Industry 4.0 the problem of technological unemployment has been highlighted in the international literature (Gimenez & Santos, 2019). However, the intensity and rate of manifestation of such problem are different in each country.

Note that in Brazil, industrial employment was increasing until 2013, but the economic reversal that began in 2014 caused a significant drop, affecting most industrial branches (Borghi & Bacic, 2021). The recovery of employment in manufacturing depends mainly on the expansion of production and growth in labor productivity.

In an unfavorable context of specialization in low complexity sectors and tasks, the Brazilian industry has already suffered from the effects of the new wave of automation, and the perspective is that such effects will manifest themselves even more severely throughout the current decade, increasing the challenges that must be overcome by industrial policy in Brazil (Suzigan, Garcia, & Feitosa, 2021).

The purpose of this article is to glimpse possible scenarios in the face of the new digital transition, discuss the probable impacts of technological unemployment on the Brazilian industry, and stimulate the debate about the most adequate policies to face the problem.

1. The Brazilian industry in the new digital transition

After the peak of the Brazilian industrialization process in the early 1980s, the national manufacturing production not only lost share in the value added but also entered into a specialization path with its own characteristics. Over the following decades, the Brazilian industry became more specialized sectorially in mature technological sectors, intensive in scale and in natural resources, but also, within the logic of a production with well-defined vertical specializations, became a manufacturing system buyer of imported technologies and inputs.

The crisis of the 1980s, by leading the destructuring of the policies of fomentation to the productive sector and of support to industrialization in the phase of dissemination of the technologies of the microelectronic complex and of the information and communication

technologies, led to the partial internalization – with little density and with low technological capacitation – of the sectors referring to the Third Industrial Revolution. One of the effects of this destructuring was the inability to articulate the trajectory of specialization of large national companies with a capital goods sector of greater technological complexity. The process of deindustrialization that continued throughout the 1990s hit the more technology-intensive sectors harder, resulting in the virtual absence of important players in sectors at the forefront of the digital technological paradigm.

The size of the domestic capital goods sector, with relative technological backwardness, became a fragile element to behave as an inducer of the use of new technologies and to give greater support to an investment cycle based on domestic demand at a time of technological upgrading of production plants. The 1980s and 1990s defined a pattern of specialization of the large national companies marked by the exit from the sectors of greater technological intensity and greater dependence on public investments, precisely concentrating the efforts on strategies directed to the sectors of greater technological maturity and more intensive in natural resources (Castro, 2001).

The technological cumulativeness between information and communication technologies and the enabling technologies of the Fourth Industrial Revolution results in less capacity in the Brazilian industry to develop the new technologies of Industry 4.0. Given the specialization profile of Brazilian companies in recent decades, the Brazilian industry has low technological know-how in technologies related (or with technological proximity) to the technologies of the Fourth Industrial Revolution, as well as little proximity between research institutions and companies developing such technologies.

The relative delay between the current institutional structure and its necessary adaptation to the characteristics of the next technological paradigm imposes greater urgency in the definition of policies in this direction. The time required to restructure the industrial policy support instruments, the consolidation of the main players in the new technology markets and the concentration of these markets may render unfeasible attempts to promote Brazilian companies. In this sense, there is a relationship between the timing for structuring development policies and the evolution of technological trajectories of the Fourth Industrial Revolution paradigm, which if lost, Brazilian industry will hardly be able to develop competitiveness in new technologies.

Taking the process from research and development of the application of new technologies to the consolidation of a market and a chain of suppliers of final goods and inputs, the entry of new firms generally becomes more difficult the further the consolidation of these markets evolves due to the ability of large firms to impose typical barriers to entry – *e.g.* scale advantages, property rights, among others. The timing of entry into new markets is, therefore,

a fundamental factor in the efficiency of policies. The institutional backwardness of the Brazilian fostering and innovation system creates a certain urgency for institutional restructuring and more expressive policy actions.

From the perspective of technological assimilation, the sectorial specialization of Brazilian industry has been directed toward a profile more oriented toward the consumption of technological packages, innovation through the acquisition of capital goods and the modernization of production processes and/or, at best, only toward the incorporation of technologies generated in other industrial sectors in their final goods. The characteristics of the current structure of Brazilian industry indicate a low capacity to react to the effects of technological unemployment, especially those that will result from the evolution of the new phase of industrial automation. This fragility stems, above all, from the low participation of domestic companies in strategic sectors for the development of new technologies of the Fourth Industrial Revolution.

The new technological paradigm finds the Brazilian industrial system in a situation of fragility and with little possibility of absorbing the spillovers of new technologies in the form of innovation in its products. The Brazilian industrial system, however, is still endowed with a few large companies, with a significant degree of internationalization and which have production plants that are leveled with the competitive requirements of international benchmarking. The large Brazilian companies have the operational scale and financial capacity to assimilate the new production technologies, mostly labor-saving, through the purchase of equipment, machine tools and automation systems. The technological updating of the production lines can reproduce a phenomenon similar to what happened in the 1990s, when the modernization of the production lines took place in a context of low production growth and reduction of labor employment in manufacturing production.

Considering the characteristics of the current Brazilian industrial structure, the digital transition should have the effect of increasing the heterogeneity of productivity among the different sizes of companies. Large companies with greater capacity to finance investments in automation and with the ability to upgrade their production plants through the acquisition of new technologies embedded in capital goods and services provided should increase productivity compared to smaller companies. This effect may lead to an even greater widening of the already existing and high productivity gap between large firms and medium-sized firms in Brazil (Nogueira, 2019).

These current characteristics of the Brazilian industrial system lead us to believe that the assimilation of new technologies will have a significant impact on the reduction of industrial employment, while there is little possibility that the change in the technological paradigm will become an opportunity for increasing the participation of Brazilian industry in

international trade in capital goods or durable consumer goods (with more technological intensity), which could mitigate technological unemployment. Even if national companies, in other sectors, can increase their participation in international trade, this will probably be accompanied by a greater use of technology not produced locally and a bigger consumption of imported inputs.

In this sense, we can describe the present situation of Brazilian industry as a system that increasingly imports technology and increasingly produces less, which indicates the difficulties that will be faced to mitigate technological unemployment. The need to mobilize investments in modernization of production plants may also generate a reduction in business areas and certain production lines, increasing the degree of specialization of large Brazilian companies and contributing to the deepening of the deindustrialization process.

If we take into consideration that the arrival of the new technological paradigm will mean, above all, a deepening of automation and digitalization processes, many of the production activities of the Fordist type, that is, based on routine tasks organized in a sequential manner in production lines and which are still labor-intensive, will be among the most affected. The predominant profile of the jobs generated in Brazilian industry is among those that will be most affected by the automation processes. Therefore, in addition to the risk of deepening the deindustrialization process, existing sectors will have their job creation capacity reduced by the advancement of the automation process (Manyika, Chui et al., 2017).

Because of the specialization pattern of Brazilian industry and the characteristics of the next technological paradigm, policies aimed at mitigating technological unemployment should take into consideration the need to promote structural changes, such as the need to strengthen new activities of greater technological complexity in which domestic industry has little participation. These changes should be guided both in the sense of seeking to promote sectors that will have their demand increased due to the technological upgrade to the next technological paradigm, such as capital goods and durable consumer goods that are more technology-intensive, as well as seeking to create capabilities in technological services associated with manufacturing activities.

In the period after the 1990s, the sectors that generally act as diffusers of new technologies, such as machinery and equipment, electro-electronics, chemical and pharmaceutical products, transport material, among others, were sectors especially affected by the scarcity of support policies and by the low competitiveness of the Brazilian industrial system as a whole in face of the increase in Asian production. The sectorial specialization of the domestic industry results in a structural difficulty in assimilating the next technological paradigm and mitigating the effects of technological unemployment caused by the new digitalization wave.

The incomplete incorporation of the technologies of the Third Industrial Revolution has resulted in a poor capacity to increase the participation of Brazilian companies in services related to the production of industrial goods and, therefore, also in a poor capacity to exploit the technological services niche in the next technological paradigm. The specialization profile of national industry is one of the main obstacles to the diversification of industrial activities towards activities of greater demand related to the next technological paradigm and to being able to contain the effects of the increase in automation. In order to contain technological unemployment, it will be necessary to increase the technological intensity of products and production processes, increase the national participation in technological services linked to industrial goods and direct efforts towards the creation of capabilities in the production and differentiation of products in the electronic and information and communication technology (ICT) complex.

Several international studies and reports on the effects of the Fourth Industrial Revolution on the structure of occupation point to the shift of employment from the factory floor to services related to industrial activity and, in this sense, list a series of skills and abilities that will be key to the inclusion of the workforce in the new technological paradigm (Organisation for Economic Co-operation and Development [OECD], 2016; Manyika, Chui et al., 2017; World Economic Forum [WEF], 2020). This trend of expanding the activities of the tertiary sector coupled to industrial activity – already present since the rise of the microelectronics paradigm – should intensify, bringing to the center of the debate the need to also establish policies to promote the technological services sector, which will concentrate the opportunities for labor reallocation.

The report presented by the World Economic Forum in 2020 (*Future of jobs*) presents data that corroborates the expectation of a greater intensification of the dissemination of digital technologies due to the coronavirus pandemic. The intensification of electronic commerce, the need to perform tasks with fewer human beings and the cost adjustments caused by the retraction of world trade have acted to promote the increased use of Industry 4.0 enabling technologies, shortening the adaptation time of national economies for the reallocation of labor and increasing the potential of technological unemployment (WEF, 2020).

The report calls attention to the need to also intensify policies to mitigate the effects of anticipating the adoption of new technologies because of the pandemic, since the reallocation of labor is expected to occur at a much slower pace than unemployment due to the replacement by machines. The 2008 crisis showed that the recovery of international trade in a scenario following a violent downturn can be marked by an increase in the degree of industrial concentration and a fiercer competition for the occupation of markets at the time of

recovery, with significant competitive advantages for those who take the lead (Milberg & Winkler, 2010). The intensification of international trade volatility based on global value chains can also act as an element in anticipating the use of Industry 4.0 technologies.¹

In this sense, the restructuring of international trade in the post-pandemic period should confirm the tendency to accelerate the pace of adoption of new technologies as a strategy at a time of intensified competition for markets. As many of the automation and digitalization technologies have already been induced because of sanitary conditions, this movement should gain strength with the intensification of competition.

The mentioned report of the World Economic Forum, published in 2020, confirms this trend when it points out that, during the last decade, there has already been an increase in incentives for greater integration of production lines through intelligent automation, due to productivity gains and increased competitiveness of developed countries against developing countries. The dissemination of intelligent automation processes would serve, in the post-pandemic context, to reduce the use of labor, thus reducing the differential in production costs between developed and developing countries, with the reduction of labor costs. This may be one bias of developed countries' production stimulus policies in the post-pandemic.

Companies surveyed in the World Economic Forum report mostly stated plans to accelerate the digitization of work processes, expand the use of remote work and task automation. About one-third of the companies stated that they intend to accelerate organizational transformations, reallocate labor to different tasks, and reduce the employment of labor, which shows a widespread expectation of restructuring business practices in the post-pandemic. Although almost half of the firms stated that they intend to retrain their workers for reallocation to different tasks, the possibility of reallocation within firms depends on the degree of diversification of activities and the specialization of domestic firms within value chains.

In this way, the specialization profile of large domestic companies leads one to believe that organizational changes will have little impact on the reuse of labor dispensed by technological unemployment in domestic production. It should be remembered that the possibility of reallocating labor in Brazilian industry is severely compromised due to the high degree of use of imported inputs, especially inputs of greater technological complexity that have greater use of technological services and that will suffer less from technological unemployment. In the next section, we discuss the relations between the characteristics of the production structure of Brazilian industry and the changes that the new digitalization wave is expected to bring about in industrial employment.

¹ In many cases, development depends on "upgrading" in global value chains, but this is not enough to improve wages or employment standards (Milberg & Winkler, 2013).

2. Brazilian productive structure, the transformations in employment and policy proposals

The current changes point to an increased demand for technological services, especially those related to data processing and information analysis, information digitalization, and the application of artificial intelligence to processes and services. The demand for these activities will mean a demand for workers who are less specialized in routine activities and rigid specializations, more capable of using and translating the information generated and of managing networked activities.

The studies on skills and competencies also highlight that the so-called soft skills will be of great relevance, since the most mechanical and routine tasks will be the most affected by the replacement with robots and digital processes. These skills depend on a consistent education since elementary school, and it will not be possible to build these skills in the short term or in retraining processes. Another part of the most demanded skills under the new paradigm is related to the mastery of programming language and algorithms; these skills will be at the base of activities related to the control and processing of information that should become significantly more widespread.

The low degree of digitalization of economic activities in Latin America and the low degree of automation of manufacturing activities in Brazil when compared to the number of multi-purpose robots per worker in advanced countries is indicative of the technological backwardness and the existing space for scaling up digitalization and automation processes in Brazilian manufacturing (Gimenez & Santos, 2019). Although studies on the overall impact of technological unemployment are somewhat inconclusive, expectations about the regional effects of the waves of digitalization and automation on Latin America are that the region is especially susceptible to technological unemployment either by labor substitution or by deepening the deindustrialization process.

The direction these changes in the demand for manpower training reveals how poorly Brazil is positioned in terms of its worker training structure, from primary and secondary education to technical vocational and higher education. The adequacy of the manpower training system, starting with primary education and passing through National Service of Manufacturing Workers Education (SENAI in its Portuguese acronym) and other industrial manpower training institutions, to the needs of the next technological paradigm requires a longer timeframe and more far-reaching public policies, this may be a significant limiting factor for a readjustment of Brazilian industry to a world of greater diversification towards technological services.

Brazil is still especially poorly positioned in the portion of the active population with some developed digital skills, the report cited from the World Economic Forum presents as data that about 36% of the active population against an average of about 60% in developed countries and far below developing countries like India (49%), Indonesia (60%), China (71%) and even Latin American countries like Argentina (50%) and Mexico (42%). The result of the survey applied to Brazilian companies confirms the previously mentioned trend, that the tasks that should undergo greater replacement are assembly activities in factories, accounting activities and machinery repair and maintenance (WEF, 2020).

The current situation of the Brazilian production structure and the trends caused by the new technological paradigm in the occupational structure suggest a low capacity to offer new jobs to compensate for technological unemployment in the traditional industrial sectors. The importance of rethinking the specialization of the Brazilian production structure toward more complex sectors, focusing on the links in the production chains more related to the production of intangibles and technological services contained in industrial goods, seems to be a central issue if the effects of technological unemployment are to be truly reduced.

Even in the low and medium-low technology industrial sectors, there is a potential to incorporate technological services that deserves special attention (Instituto Euvaldo Lodi [IEL], 2017). Even within the specialization profile of Brazilian industry, there are possibilities of technological sophistication to be explored in medium-tech sectors. In addition to the sectoral specialization of Brazilian industry, the focus on assembly activities and the low participation in the development and production of technology and innovations in sectors where domestic companies are predominant make workers in these companies susceptible to technological unemployment.

This scenario indicates that it is necessary to focus on policies to change the specialization profile of Brazilian industry towards its greater technological sophistication and greater capacity building in industrial services, as a possible strategy for reducing the impact of technological unemployment on the occupational structure. In parallel, within the specialization profile of domestic industry, it is fundamental to increase the effort in spending on research and development and innovation by domestic companies.

The Social Economic Forum report adds to other studies (Manyika, Sinclair et al., 2012; OECD, 2016; Manyika, Chui et al., 2017; Tcherneva, 2020) that highlight the potential role of the public sector in reducing the effects of technological unemployment by expanding the supply of public services and modernizing them. As new technologies will have a broad impact on the way public services are controlled and delivered, increased investment in the modernization and digitalization of public services may also be a viable strategy for

reallocating and retraining labor for activities that involve the new technologies and for activities that will suffer little impact from automation processes.

The trends indicated suggest that the long crisis of the Brazilian industrial system has hindered the capacity to assimilate the new paradigm beyond the standardized consumption of new technologies applied in production processes or in inputs related to final goods. The reversal of this picture, in order to reduce the effects of technological unemployment, requires the creation of a long-term strategy to make it possible to retrain the workforce, but also policies to promote activities of greater technological complexity.

Initiatives aimed at increasing the participation of segments with greater technological sophistication should be in addition to policies designed to take advantage of the existing potential for generating higher skilled jobs in traditional sectors by increasing investments in innovation and product differentiation (Centro de Gestão e Estudos Estratégicos [CGEE], 2020). As the enabling technologies of the new technological paradigm will have impacts on practically all productive activities, the customized application of new technologies in specific production processes will create a demand for technological services, including the modernization of less complex production processes.

It is important to guarantee policies that allow greater insertion of national companies in the market of productive process technology development as a way to advance in activities of greater technological sophistication starting from the Brazilian industrial base. Even though the potential for reallocation of labor is very uneven among the industrial sectors, within the Brazilian sector specialization there is still a significant potential to be explored in terms of greater sophistication of production processes and in the development of innovations and product differentiation.

In a study on the employment of masters and doctors considering the technological intensity and the branch of economic activity, CGEE (2020) shows that, between 2010 and 2017, there was a significant increase in the employment of masters and doctors in all technological intensity ranges among the manufacturing industry sectors, including in the low and medium-low technological intensity sectors. As expected, the document also shows that employment of masters and doctors grew at higher rates in sectors of higher technological intensity, which reveals the limits of the incorporation of high-skilled labor within a productive specialization profile centered on sectors of low technological intensity.

As there has been a growth in the employment of masters and doctors in the less technology-intensive sectors in Brazil, the capacity to absorb skilled labor in these activities can hardly grow at a rapid pace without an expansion in production and an increase in the participation of these sectors in world trade. As these are activities that are not listed as those

with greater investment in innovation, in comparative terms with other industrial sectors, the possibility of employing scientific manpower is limited, and it is difficult to expect it to continue growing at a rapid pace without a greater effort in the development of technology and activities related to process innovations.

The small participation of Brazilian companies in technology-intensive sectors reduces the capacity to absorb labor in knowledge-based activities, which will be less affected by technological unemployment. However, this reduced participation of Brazilian companies in the development of product and production process innovations in the sectors in which they operate is also a limiting factor for the increase in demand for labor in knowledge-based activities. The articulation of policies to improve supply conditions with policies of incentives to diversification towards a vertical specialization of greater complexity would be the most appropriate to enable the exploration of these niches.

In the case of some more technology-intensive sectors, Brazil has some institutional frameworks and public policy instruments that enhance the capacity to generate jobs with higher technical and scientific qualifications. It is important to note that the greater the technological complexity of a sector, that is, its ability to mobilize technological capabilities generated in other productive activities, in general, the greater its ability to generate jobs with higher skill requirements (Hidalgo, 2009; Gala et al., 2018). Even if the more technology-intensive sectors undergo a significant wave of automation, as expected, the internal reallocation of labor in these sectors will be simpler than that of the less technology-intensive sectors.

The technological complexity of the production structure also defines the diversification capacity of local firms (Hidalgo, 2009, 2021). Therefore, the technological sophistication of a productive sector also defines its capacity to diversify and advance into other activities of greater technological sophistication. The more technologically complex sectors, thus, provide a base to be exploited for the potential to diversify into other activities and for the superior capacity to absorb more specialized labor and less inclination to be replaced by automation processes.

In the case of the health industrial complex, for example, there is a great potential for incorporation and development of technology itself from the demand by the public health system – Sistema Único de Saúde, commonly called SUS. The specificity of the health sector in Brazil (endowed not only with a wide-ranging public system, but also with a relatively sophisticated research system) would allow the use of the public sector as a demander through the modernization of the public health system. For this, it is necessary to reinforce again the relevance of the articulation of public policies that would create demand with policies to foment the more complex activities linked to the industrial complex of health.

The industrial health complex is a good example of the possibilities of exploring specific niches from the impacts of new technologies. The technologies of the Fourth Industrial Revolution will have impacts in the areas of diagnosis, clinical analysis, surgical intervention, among others things, but should also have impacts in the areas of training and education of health professionals (WEF, 2020). In sectors where it is possible to articulate development policies with the demand from the public sector, the exploration of the various possibilities opened up by the technological transformation of tasks within a production complex can significantly reduce the effects of technological unemployment.

This statement can be extended to various activities related to the provision of public services and collective consumer goods. There is a set of policies being articulated, especially in the post-pandemic period, that aim to create demand for the new technologies that will come from the modernization of public services and infrastructure in general. These policies reposition the public sector as a vector for the articulation of policies both on the demand side and policies to foster competitiveness and innovation. Public investment, due to the characteristics of the new industrial paradigm, should become a strategic element in creating opportunities for the sophistication of the activities of domestic companies and facilitate the assimilation of new technologies by domestic industry (Mazzucato & Penna, 2015).

In the low technological intensity manufacturing activities there is still a potential to be explored in the reallocation of labor through the strengthening of the set of small and medium enterprises (SMEs) with a greater focus on product differentiation or development of customized applications of the enabling technologies of Industry 4.0. As one of the characteristics of the technologies of the new paradigm is their high customization in the development of specific applications in various areas, there is a window of opportunity for strengthening technology-based companies by strengthening the links of cooperation between companies and the national innovation system.

The sophistication of the SMEs system is a strategy that should be followed by a large number of policies to promote the productive system in industrialized countries, based on the logic that the development of knowledge-intensive activities with a low production scale will be one of the main fronts for reducing unemployment caused by technological progress in industrial automation processes. One of the challenges, in this sense, is the adequacy of the promotion system to the financing of technology-based companies and the development of an economy of technological services.

The creation of a regime of incentives to increase the technological complexity of Brazilian industry is a necessary step to increase the capacity of the Brazilian industrial system to reallocate and retrain its workforce. The design of policies to incorporate new technologies

with the training of domestic producers has better efficiency when it occurs in the phase of dissemination of technology in its standardization phase. This fact defines a specific schedule for planning and implementation of development policies, and the loss of implementation timing may mean, in some cases, the definitive loss of the possibility of carrying out a feasible policy. The disarticulation of industrial, scientific, and technological policies at the moment of change in the technological paradigm may subsequently create the need for reactive policies to deteriorate the competitiveness of the industrial system, with a high social cost.

Despite the problems related to its productive specialization, Brazil is not far behind international experience in the construction of policies to reduce the effects of technological unemployment. The regulatory survey conducted by CGEE (2021), for example, although it has not identified the existence of significant legislative frameworks to inhibit technological unemployment in Brazil, points out that there are also no explicit regulatory changes in the rest of the world to prevent or curb technological unemployment, with labor market protection being done mainly by encouraging collective agreements and discouraging layoffs (CGEE, 2021). However, it should be taken into account that policies to encourage the absorption of new Industry 4.0 technologies by the Brazilian industrial system should have more significant impacts than in more developed countries, given the technological gap of industrial production plants and the labor-saving effect that new technologies will have on this industrial structure.

In the international scenario there has been the dissemination of a set of major industrial policies aimed at consolidating the new technological paradigm, but also at strengthening the links between production clusters and research institutions, with a focus on strengthening the systemic competitiveness of national industries. In common among industrial policy proposals in developed countries is the concern with strengthening the links between companies and public research institutions and the focus on technological progress and competitiveness of the national manufacturing system as a whole (O'Sullivan et al., 2013).

The post-pandemic international conjuncture suggests a scenario of intensified international competition, with the possible acceleration of the dissemination of part of the technologies of the Fourth Industrial Revolution and an environment marked by greater state activism. In many cases, all these dimensions appear articulated in programs aimed at promoting structural changes in national economic systems, which, in turn, should consolidate the technological standards of the next paradigm. In this sense, there is insufficient attention in the Brazilian debate to the Brazilian situation in the face of the changing international conjuncture and to the creation of adequate instruments for promoting the competitiveness of national industry beyond cost factors.

The possibility of reversing the fragmentation of certain production chains, giving way to more integrated production systems, reduces the potentiality of a set of industrial policies, focused on reducing operating costs and attracting foreign investment to boost the participation of domestic companies in global value chains. One of the issues involved in this industrial policy strategy is the possibility of stagnation in the expansion of global value chains or their partial reversal (Dachs & Zanker, 2015), which would result in increased competition within value chains and a reduction in the ability of intermediate links to obtain a significant share in value added.

This change implies the need to think about the possibilities existing in each sector in relation to its current structure in Brazil. In the case of the health complex, for example, even though there is a certain scarcity of important players of national origin, the existence of a public system of great coverage enables greater integration between the generation of innovations and the creation of interfaces with users, and is an important differential to be taken advantage of by policies to promote the productive sector.

The Brazilian development system – including public banks, financing agencies, guarantee funds, among other instruments to promote the productive sector – dates back to the Fordist-based industrialization process in Brazil (Suzigan & Furtado, 2010). The available instruments are generally aimed at financing companies that produce goods and operate in markets that are already stabilized. In this sense, there is a need for a better adaptation of the fostering system to the financing of technological services, technology-based companies and innovation processes carried out in institutional cooperation.

Although the Brazilian system has some instruments for financing innovation, the greater insertion of Brazilian companies in specific niches opened up by the dissemination of new technologies requires a diversification of existing instruments and their better adaptation to the characteristics of the new paradigm. The business structure that will be promoted by the new technological paradigm tends to be characterized by a larger number of companies entering the development of the customized application of enabling technologies, aimed at new markets and with great uncertainty about the evolution of these markets.

The applications of new technologies and the development of a market for technological services will require instruments that are more oriented to the higher risk financing pattern typical of innovative processes. When international experiences are observed, the role of public funding agencies in acting in the phases of higher risk and with greater financial volume becomes evident; generally, long-term credit modalities are less functional than direct participation in capital or direct subsidy (Sau, 2007). Although in the last decade there has been a greater diversification of these instruments in Brazil, many have

had their funds reduced and depend on a better adaptation in relation to the ways of developing and using the technologies of the Fourth Industrial Revolution.

Reducing the trade off between technological progress and employment demands the creation of a set of instruments for the constant requalification of labor, but also requires progress in adapting the Brazilian productive structure to activities with less of a tendency toward technological unemployment and which focus on more dynamic markets in international trade. This strategy can be summarized in a greater focus on the sophistication of industrial services performed domestically and on increasing the technological complexity of domestic production.

The establishment of knowledge-based activities and the production of goods with greater technological differentiation may create a productive specialization profile less susceptible to technological unemployment. In the more scale-intensive sectors, the new technologies should provide greater capacity for process control and automation, the elimination of human labor in routine control and administrative tasks, and probably an increase in the competitiveness of production on smaller and more automated scales.

In this way, it is a fundamental point in the debate to discuss the possibilities of encouraging other specialization routes for national industry. An industrial policy that encourages the development and diversification into more technologically intensive activities, such as consumer durables and capital goods, would be an important strategy to increase the supply of jobs in sectors with greater capacity for product differentiation, the development of customized technological applications and with greater intensity of technological services incorporated in the production of goods.

The technological intensity of the production structure is fundamental for determining a broader horizon of possibilities for productive diversification. Therefore, a policy that encourages productive specialization towards more technologically intensive sectors provides a more appropriate prior basis for responding to policies to mitigate technological unemployment. The more complex sectors, in general, have greater linkages with the high productivity service sector and tend to be sectors with a greater capacity to retain labor during the next digital transition.

As these sectors have a wider range of knowledge-based activities involved in the production of their goods, the expansion of national production would also imply an increase in the supply of jobs with characteristics less susceptible to substitution by automated systems. Therefore, the diversification of the national industry in this sense increases the possibilities of managing policies aimed at reducing technological unemployment.

In terms of public policy design, it is possible to develop a pattern of vertical specialization more focused on technological development of capital goods and production processes in sectors where domestic companies have competitive advantages. In addition to the lower cost of this type of policy compared to policies aimed at changing the pattern of sectoral specialization, it allows the reallocation of labor within the productive complexes themselves and tends to strengthen the competitiveness of Brazilian companies already established.

A second axis of necessary policies is the updating of certain characteristics of the national innovation system, as has already occurred in central countries. In recent years, the productive development policies of advanced countries have been directed towards the decentralization of research infrastructure, greater geographical specialization in relation to productive clusters, and a greater targeting of Industry 4.0 enabling technologies (Rocha, 2019). Although the Brazilian system has some characteristics consistent with this bias verified in international policies, it is necessary to expand cooperation relations between research institutions (R&D) and companies, and bring these institutions closer to local production complexes as a way to facilitate the improvement of applications developed specifically for products and production processes.

A last axis would be the institutional updating of certain funding mechanisms, the Brazilian system of funding and financing productive activities and innovation needs to be updated given the characteristics of the new technological paradigm. Both the national innovation system and the funding system have characteristics typical of Fordist institutions, lacking better adaptation to the expansion of the incorporation of services in manufacturing activities and to the development of innovations through institutional cooperation and linked to technology-based companies that emerge in the innovation process itself.

Interesting initiatives such as the public call for venture capital conducted by Finep and other lines of funding opened by state research funding agencies are examples of policies that can be followed. These initiatives have adequate direction, and may be resumed or expanded in some cases. International experiences also show that sectorally specialized funding agencies present good results in terms of efficiency of public policies and have been recurrently adopted as a way to encourage productive diversification towards more dynamic areas.

It is worth noting that the post-pandemic international environment will be characterized by the extensive use of industrial policies and protection of local capital. In this scenario, the practice of public policies must be based on the realism of the dispute for international markets and the use of instruments to support the competitiveness of companies. Failure to use the available instruments may mean an unleveling of competition conditions with the deterioration of the capacity of Brazilian companies to compete in this

scenario. In this case, it is worth following international practices and using the available instruments to promote the local productive sector, directing the incentives to activities that allow the reallocation of labor displaced by technological unemployment.

Concluding remarks

The definition of a general plan of action towards the reduction of technological unemployment should include a set of complementary actions concerning the adaptation of the national manufacturing system to the characteristics of the Fourth Industrial Revolution. Any strategy must include a focus on changing the sectorial specialization profile of Brazilian industry – towards greater technological complexity – as well as a regime of incentives to move the vertical specialization of Brazilian companies towards areas more focused on process and product innovation.

In the current process of digital transition, data control and management activities will also be highly strategic to create competitive advantages for entry into sectors that will undergo a more intense process of automation. The crossover of data and the need to supply the algorithms of the systems can create barriers to entry with regard to access and operational scale of data processing, regulation of access to local population data thus becomes a concern directly linked to industrial policy.

Beyond these issues, it is necessary to design industrial, scientific, and technological policies that are more coordinated with the high echelon of government, that is, that are closer to the decision-making centers, with greater ability to guide the hierarchy of public policies and that have greater prominence within the logic of resource allocation. As the adaptation to the new technological paradigm requires changes that extend from the educational system to the financial system, there is no possibility of success without the centralized coordination of actions and without these policies being at the top of the priorities.

Brazilian manufacturing will face even greater competitive pressure if it does not adapt its production plants to the new automation processes, even if large companies have the capacity to upgrade. If there is no policy coordination, in addition to the reduction in industrial employment, the likely result will be the amplification of heterogeneity in Brazilian industry and the deepening of the deindustrialization process. The period that begins with the pandemic will be a period of rapid dissemination of new technologies through massive plans to foster the productive sector and innovation, and it remains for Brazil to build its path to this new economy.

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