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DOSSIER: INDUSTRY 4.0

The effects of Industry 4.0 on employment and wage inequality:
Back to basics

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Abstract

This article develops a critical assessment of the literature correlating the technological advances of Industry 4.0 to worsening conditions in unemployment and wage inequality. Some of the limits and inconsistencies of this literature are highlighted, particularly its inadequacy to explain contemporary movements of manufacturing and its social consequences. We then argue that an analysis based on post-Keynesian political economy seems more appropriate to studying the topic, since it underlines the importance of effective demand and political and international contexts in the determination of employment and wages. The article concludes by rejecting the mainstream hypothesis that correlates unemployment and/or inequality with technological progress.

Keywords: Industry 4.0; Technology; Unemployment; Inequality.

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Os efeitos da Indústria 4.0 no emprego e na desigualdade salarial:
De volta ao básico

Resumo

O artigo desenvolve uma leitura crítica da literatura que correlaciona os avanços tecnológicos da Indústria 4.0 com pioras nos níveis de desemprego e de desigualdade salarial. Alguns dos limites e inconsistências dessa literatura são destacados, especialmente a sua dificuldade de explicar movimentos contemporâneos da manufatura e suas consequências sociais. Argumenta-se então que uma análise baseada no arcabouço teórico da economia política pós-Keynesiana parece mais adequada para o estudo do tema, pois tal arcabouço sublinha a importância da demanda efetiva e do contexto político e internacional para a determinação do nível de emprego e salário. O artigo conclui por rejeitar a hipótese teórica do mainstream econômico que correlaciona desemprego e/ou desigualdade com progresso tecnológico.

Palavras-chave: Indústria 4.0; Tecnologia; Desemprego; Desigualdade.

Los efectos de la Industria 4.0 en el empleo y en la desigualdade salarial:
Volver a lo esencial

Resumen

El artículo desarrolla una lectura crítica de la literatura que correlaciona los avances de la Industria 4.0 con el deterioro de los niveles de desempleo y desigualdade salarial. Algunos de los límites e inconsistencias en esta literatura son resaltados, especialmente su dificultad de explicar los movimientos contemporáneos de la manufactura y sus consecuencias sociales. Se argumenta entonces que un análisis basado en el marco teórico de la economía política pos-keynesiana se ve más adecuado para el estudio del tema, porque tal marco subraya la importancia de la demanda efectiva y del contexto político e internacional para la determinación del nivel de empleo y salario. El artículo termina rechazando la hipótesis teórica del mainstream económico que correlaciona desempleo y/o desigualdad con el progreso tecnológico.

Palabras clave: Industria 4.0; Tecnologia; Desempleo; Desigualdad.

Les effets de l'industrie 4.0 sur l'emploi et les inégalités salariales:
Retour aux sources

Résumé

L'article développe une lecture critique de la literature qui relatione l'avancement technologique de l'industrie 4.0 avec une dégradation des chiffres du chômage et d'inégalité salariale. Les limites et inconsistances de cette literature sont soulignés, surtout son incapacité d'expliquer les mouvements contemporains de la manufacture e leurs conséquences sociales. On argumente ensuite qu'une analyse basée sur le cadre théorique de l'économie politique post-keynésienne semble plus appropriée à l'étude du sujet, car elle souligne l'importance de la demande effective et du contexte politique et international pour la détermination des niveaux d'emploi et de salaire. L'article finit pour rejeter l'hypothèse du mainstream de l'économie qui fait un lien entre chômage (et/ou inégalité) et progrès technologique.

Mots clés: Industrie 4.0; Technologie; Chômage; Inégalité.

Introduction

The productive structure of developed countries is increasingly constituted by devices that belong to what is now widely known as "Industry 4.0". The growing automation and interconnection of manufacturing activities related to this new paradigm have revived the debate around the impacts of technological advancement on employment, wages and inequality in the global economy. Indeed, this discussion, which goes back to the very origins of the economic science, is being resumed in various media – but in a manner that has compelled some of the preeminent advocates of the theoretical mainstream to reconsider a few of their hitherto more conventional and optimistic propositions on the matter.

Succinctly, the idea that the recent technological progress would have harmful effects on employment and/or income distribution has become ascendant in the academic environment, as well as in international institutions. The works of Frey and Osborne (2013), Brynjolfsson and McAfee (2014), Autor (2015), Arntz, Gregory and Zierahn (2016), Acemoglu and Restrepo (2017), Allen (2017), among others, show the current relevance of this line of reasoning. In much the same way, reports from McKinsey Global Institute (MGI, 2017), International Monetary Fund (IMF, 2018), Organisation for Economic Co-operation and Development (OECD, 2018) and Comisión Económica para América Latina y el Caribe (CEPAL, 2017) endorse the perception that the automation related to Industry 4.0 may present problems to the allocation and remuneration of labor. In broad lines, all these studies state that labor and capital markets would now be operating under circumstances that prevent innovation from delivering social progress – a narrative that conflicts with the historical register of social benefits provoked by technological enhancement in production.

It would be expected that such a narrative change would stem from well stablished facts, presented by sound theory. However, the present article argues that there is no theoretical base for this change. Our hypothesis is that the conventional assessment of the effects of technological progress in macroeconomic variables is inaccurate, and it has wrongly favored the supposition of causality between the recent technical innovations and unemployment or inequality.

In order to validate this hypothesis, the present article will take a less orthodox stance on the subject, using a framework inspired by post-Keynesian political economy.[1] Firstly, it will

[1] This definition is not supposed to affiliate this article with any particular group within Lavoie's (2014) depiction of the schools of thought belonging to post-Keynesianism. We use the denomination in its broadest sense, in an attempt to take hold of its most interesting features for the present study. We highlight amongst the various pieces of work that compose our view on this article the model for comparative political economy from Stockhammer (2020); the modeling of labor market from Lavoie and Lang (2018); and Cesaratto, Serrano and Stirati's (2003) model on the effects of technical progress on wages.

review the predominant literature on the subject, paying special attention to the aforementioned articles and reports. Secondly, the article will proceed with an alternative analysis of some contemporary facts that contradict the main narrative on the effects of industry 4.0 on employment and inequality. Finally, it will aim to pinpoint some of the insufficiencies on the predominant models used to study the matter, presenting at the same time a more consistent framework to dealing with the subject.

Considering this line of reasoning, the article is structured in four sections in addition to this introduction. In the section 1, we provide a definition of Industry 4.0 coherent with a critical reading of contemporary technological advancement. In the section 2, we proceed with a review of the main studies that have presented the correlation between unemployment and inequality on the one hand, and expansion of Industry 4.0 on the other hand. In the section 3, we draw on a critical historical assessment of the subject and consider the employment of an alternative approach to grapple with some facts that contradict the bulk of the orthodoxy on the matter. We then build on a post-Keynesian reasoning to apprehend the conjuncture of growing unemployment, wage inequality and technological progress in the contemporary productive structure. The last section presents the article's final considerations.

1. Some definitions on Industry 4.0

If we are to understand the problems arising with the new wave of technological innovation as it has been applied to production, first we need to clarify what constitutes this wave. In the present case, we need some comprehension on the meaning of Industry 4.0 – or advanced/intelligent manufacturing, as this new paradigm has also been labeled.

Any literature review on the matter will show that the past decade has witnessed the production of a plethora of studies discussing the meaning and consequences of Industry 4.0. Generally, all these studies identify profound transformations occurring on manufacturing as a result of technical progress in robotics, internet and other "enabling technologies". New possibilities of application and combination of these technologies have given room to the idea that a new industrial revolution would be imminent.[2] Schwab (2016) is one of the most well-known authors to diffuse this perspective, drawing attention to the changes that are already happening in many sectors and which could transform the way people do business and work. A very similar position is shared by big consulting firms and by popular writers, like Brynjolfsson and McAffe (2014), who identify a new "machine age" coming our way.

[2] The very origin of the term "Industry 4.0", coined in the 2011 Industrial Fair at Hannover, is a reference to a fourth industrial revolution.

Therefore, Industry 4.0 denotes a technological event that has been causing concern over new arrangements on productive processes. Its main element is the dissemination of cyber-physical systems, constituted by the interaction between algorithms and artificial intelligence, which are in their turn underpinned by a new type of machinery connected to the internet.[3] To the private companies, the ultimate goal of implementing this technology would be to secure a stricter control over their supply chains, which would allow for the constitution of self-controlled intelligent factories (Oztemel & Gursev, 2018).

The concept of Industry 4.0 is hence associated with this innovative electronic and mechanical apparatus based on a technology that has the potential to create new production platforms and, consequently, relocate workers. This new structure is constituted by the "enabling technologies", which comprise artificial intelligence, robotics, additive manufacturing, big data, Internet of Things, and cloud computing (Martinelli, Mina, & Moggi, 2019).

Notwithstanding all the adjectives used to describe this new technological paradigm, a few problems arise when we try to build a more precise definition of Industry 4.0. Whoever dwells on the question realizes that the concept is quite loose, and that the consensus around its meaning is restricted to a generic use of the mentioned "enabling technologies" on production (Estolan et al., 2018). This is also due to the fact that much of the technological convergence presupposed by Industry 4.0 is still in its beginning, and radical structural changes in manufacturing cannot be clearly perceived until now.

In this sense, it is of the foremost importance to take into account the considerations of Pfeiffer (2017) and Morgan (2019) on the relevance of the Industry 4.0 concept as a marketing tool. If the majority of the literature on the subject presents a charming fourth industrial revolution filled with technological possibilities, it is the task of critical reasoning to filter this discourse of its rhetorical elements and recognize its origins in institutions with political and economic interests. In so doing, we see that Industry 4.0 belongs to a wider attempt to build a consensus about the future, in which countries and companies try to obtain or reinforce their leading role in technical development by selling new machines and services. These machines and services may not be revolutionary – but they may be announced as such.

In this vein, Daudt and Willcox (2016) do not accept the revolutionary ambitions of industry 4.0 at their face value, arguing that the novelty in the contemporary technological advancement is limited to the apparent convergence and combination of the cited "enabling technologies". This convergence may offer positive perspectives to labor productivity, but to

[3] For a technical definition of "Industry 4.0", see Hermann, Pentek, and Otto (2015).

state that we are witnessing a revolutionary paradigm disruption seems exaggerated, for the impact it will cause in the international productive structure is still uncertain, and many of the technical developments being considered revolutionary "have been around for a while" (OECD, 2015, p. 10).[4] This skepticism with Industry 4.0 seems justified when we consider the most recent data on labor productivity for an advanced and rich economy like the United States (Sprage, 2021, April), which has shown little change since 2005.

Considering the purpose of this article, we will not dwell any longer on this controversy. It is important to recognize its existence, however, and to advance our position on the matter as a more consensual one, for we will treat Industry 4.0 as the set of the aforementioned "enabling technologies" being used in industry or which have the perspective of being applied to manufacturing in the near future. Even if it is not possible to delineate a clear revolutionary change for industry, the innovations that are spreading throughout the productive structure will have non-negligible effects on the working conditions, driving to a reconfiguration of labor use in the economy. After all, the diffusion of robotics and integrated production systems will probably have a lasting impact on productivity and demand new competencies from the workforce – and the latter is likely to be allocated differently. The question that arises in this context – and which motivates the present article – is then the following: the changes provoked (and yet to be provoked) by the Industry 4.0 apparatus will translate into lower employment levels or regressive wage distribution? Much of the contemporary literature on the matter answers these questions (specially the second one) affirmatively. These answers are, however, at odds with the historical experience of technological progress thus far. Let us then proceed with a critical analysis of this literature as to unravel its main assumptions and better evaluate its outcomes.

2. Industry 4.0 impacts on employment and wage according to the predominant literature

2.1. Industry 4.0 impacts on employment and wages: qualitative aspects

As already stated, the perspective of structural changes related to the expansion of Industry 4.0 has raised concerns that high unemployment and/or inequality would be the inevitable byproducts of the current technological progress. The growing empirical evidence

[4] Andreoni, Chang, and Labrunie (2021, p. 338) share this point of view but they emphasize the potential changes that a fourth industrial revolution (4IR) could bring about: "4IR technologies […] have a long history and in many aspects seem to be the result of an 'evolutionary transition' that triggers several processes of speciation within and across sectors, rather than a 'revolutionary disruption'. However, this is not to say that there is nothing new about the 4IR. There is a truly revolutionary character to it which is the technological fusion."

of worsening conditions in both indicators have resulted in a theoretical reassessment of the effects of innovation in labor markets.

The resuming of this discussion in an international academic level should probably be attributed to Frey and Osborne (2013), whose work tries to estimate the impact of innovations on the U.S. occupational matrix. According to the authors, the gains in information processing provided by new software, capable of dealing with big data, has enabled the coding of non-routine tasks, which opened the possibility of complex machines executing equally complex work. The increase in productivity provided by this new machinery, however, would not be equally shared within societies, since the elite of the labor market, the only stratum able to run and coordinate the robots, would also be in a privileged position of seizing the new value produced.

But why would this elitist appropriation be happening now, whereas in the past equally disruptive modifications in production did not end up in growing inequality? The authors respond stating that in the past, the needed capabilities for the workers to operate new machines in a production chain, for example, were relatively easy to learn and transmit. However, when computing progresses as to substitute human cognitive activities, the capabilities demanded by any high-productivity position become harder to attain – and are only at reach of those who can dedicate themselves to complex and time-consuming studying. Therefore, it would not be a surprise if a new contingent of workers willing to offer their labor force at low prices could not find employment in the new productive structure that is emerging, since they would not have the capabilities needed to do so.

Brynjolfsson and McAfee (2014) adopt an equivalent narrative. Summarily, these authors foresee a world of plenty made possible by the machines that substitute not only the human muscles, but also their brains. Nevertheless, they raise concerns that the workers lacking the capabilities demanded by the new productive structure based on computer science may end up "losing the race against the machines". From their point of view, the differences in the workers' capabilities to deal with this new "machine age" would already be the main cause of wage inequality in advanced societies. Specifically, a detachment between wages and productivity since the beginning of the 1980s could be spotted and attributed to the advancement of digital technology in industry. The authors thus argue that the educated workers' elite has been the only stratum to gain something with the productivity boost produced by the new machinery, which has not trickled down to the salaries of average laborers. The solution to that problem would be to train workers to deal with new technologies, which would allow for their hiring in newer and more productive activities (Bernstein & Raman, 2015, June).

Autor (2015) is another academic using the same framework of the aforementioned scholars, but who adopted a somewhat more optimistic reading of the facts. Based on the consideration that we have witnessed, in the recent past, a continuous creation of jobs in the most developed economies despite technological progress, he argues that there are no reasons for concern with structural unemployment, since machine substituting labor in some tasks will entail a higher demand for workers in other domains (Autor, 2015, p. 6):

> Most work processes draw upon a multifaceted set of inputs: labor and capital; brains and brawn; creativity and routine repetition; technical mastery and intuitive judgment; perspiration and inspiration; adherence to rules and judicious application of discretion. Typically, these inputs each play essential roles; that is, improvements in one do not obviate the need for the other. If so, productivity improvements in one set of tasks almost necessarily increase the economic value of the remaining tasks.

Thus, according to Autor (2015), even if the decrease in robot costs makes it profitable to substitute workers that perform simple and routine tasks, this will not translate into a wide movement in the whole economy, where specific human abilities will still be highly valuable – especially those related to social interaction and fine motor coordination. We would then identify a substitution of workers in basic manufacturing occupations, but tasks that presuppose social skills or visual and linguistic reckoning, for instance, would not disappear. From this point of view, the current technological development would have three distinctive effects over the economy: i) a smaller demand for average qualified workers; ii) a higher demand for qualified workers capable of managing and developing technological advanced business; and iii) a higher demand for workers without any specific capability, that would be employed in manual tasks which cannot be performed by robots (yet). In such a context, we would not see structural unemployment, but rather a picture of "job polarization", as growing wage inequality has been called in the literature (Goos & Manning, 2003). Here would lie the source of growing inequality in advanced economies' labor markets.

2.2. Industry 4.0 impacts on employment and wages: quantitative aspects

A strand of the mainstream economic thought has produced studies that seek to quantify the number of jobs endangered by the expansion of Industry 4.0. The aforementioned paper from Frey and Osborne (2013) is of foremost importance in this regard, because it has brought international attention to this type of research, inaugurating a whole subgenre of economic research whose focus is measuring occupation sensitivity to automation. The authors begin their study with the intuition that there will be a decrease in computers and robots costs thanks to the advancement of machine learning, which will raise the preference

for capital use in production instead of labor. Given this dynamic, they suggest a methodology to estimate the probability of jobs extinction in the near future.

Briefly, Frey and Osborne (2013) develop Autor, Levy, and Murnane (2003) definitions on cognitive complexity of U.S. occupations, assigning probabilities to their susceptibility to algorithmic treatment and automation in the next years. They estimate, subsequently, that approximately 47% of employment in the U.S. at the time of their study would be under great risk of disappearing. This high number has engendered debates around the methodology employed by the authors, but it has not deterred new studies inspired by them.[5]

Considering the purpose of the present article, it is important to highlight that Frey and Osborne (2013) do not find any evidence of "job polarization" – their study actually points to a tendency of technological progress to eliminate even the less qualified jobs. This would translate in unemployment and wage squeeze across a large spectrum of the occupations matrix. It is important to say, however, that the authors do not attempt any predictions about possible changes in the U.S. occupational matrix and, likewise, do not speculate on new jobs that the technological development could create to counterbalance the substitution of workers by machines. Moreover, the paper indicates that a substantial portion of the jobs deemed as replaceable belong to the service sector, showing that automation is likely to spread throughout the whole economy.

The basic framework of Frey and Osborne (2013) is used by Acemoglu and Restrepo (2017), whose paper is mostly devoted to studying the past. In their research, the authors develop a model where robots and humans compete for employment in different tasks. They try to estimate the impact on unemployment and wages due to the use of robots, considering the exposition of each local market to automation, and find robust negative effects of robot use. Their numbers show that something between 360,000 and 670,000 jobs have been eliminated by technological progress in the U.S. between 1990 and 2007. The paper also points that one new robot per thousand workers has meant a wage decrease of 0,5% in the whole economy, with a stronger effect in manufacturing. Nonetheless, Acemoglu and Restrepo (2017) do not speculate on occupations that could have been created by this very automation, although they admit that the U.S. economy has generated more jobs than it has eliminated in the period they analyze.

[5] Weller, Gontero and Campbell (2019) summarize some of the studies that replicate Frey and Osborne (2013) methodology to analyze other developed countries. With the exception of Singapore, they all present at least 30% of jobs in their respective countries as having high probability of automation (the figures reach 55% in Japan and 59% in Germany).

Arntz, Gregory, and Zierahn (2016), on the other hand, adopt a different methodology to evaluate job automation. Using an international framework, they consider the tasks done by each worker in different occupations according to the workers' own descriptions. This method puts automation in another perspective, for it considers that certain occupations are composed by a large number of tasks that cannot be automated. When they extrapolate their analysis to OECD countries, Arntz, Gregory, and Zierahn (2016) find relatively small numbers of occupations under risk of automation: only 9%, which are concentrated in tasks that do not demand any specific capability.

Finally, the MGI (2017) report has also become known for extending to the global economy a methodology for predicting occupation automation. Succinctly, starting with a description of the activities that integrate more than 800 occupations, the researchers estimate together with industry's specialists the foreseen impacts of technological progress in the execution of each of those activities. After that, they evaluated which occupations would be mostly modified, trying to estimate which would go through a deeper change and demand a smaller number of workers for their respective task achievement.

The report then presents 5% of the occupations evaluated as being under risk of complete automation in the next years. Nevertheless, around 60% of the occupations have at least 30% of their activities prone to automation, and they consider that 1.1 billion workers around the world could be affected by such changes. The authors underline the fact that the cost of the adjustment to automation will depend on the speed and on the productivity gains related to it. Nevertheless, they do not see any hard evidence that the labor market will be more strained in the near future than it was in the past, because we cannot spot radical transformations happening in manufacturing despite all the Industry 4.0 rhetoric. The possibility of growing wage inequality would be real, however, and dealing with it would demand worker training and actions over market failures.

2.3. Main lines of mainstream reasoning and a first step in its critical appraisal

To conclude this section, it seems useful to put forward an outline of the pieces of work reviewed above. The consensual points appear to be straightforward: firstly, there will be important changes in the occupational matrix in the near future; secondly, these changes will probably have as consequence the worsening of inequality, since the new productive structure will end up engendering a "job polarization" or even the suppression of medium and low qualified jobs. The controversies, on the other hand, start at this exact same point: when we dwell on measuring the economic and social problems entailed by Industry 4.0, the results diverge considerably – as do the policy proposals to grapple with them.

In this regard, it seems that the reviewed authors' positions on the subject follow their respective optimism with the chances of labor adaptation to the new machinery. On the one hand, the most optimist, like Autor (2015) and MGI (2017), expect a slow transition that would not reduce the quantity of jobs available. It would probably bring about wage inequality, but coping with this problem would be relatively easy in terms of policy, sufficing to train the workers. The less optimist, on the other hand, foresee a difficult adjustment, which will depend on the speed at which automation would impose itself to the production. Informational problems or issues regarding the qualified labor supply then appear as pressing questions, which should be dealt with in a resolute way by the industrialized societies.[6] Some authors, like Berg, Buffie and Zanna (2018) or Acemoglu (2019, June), fearful of the depth and swiftness of the adjustments propose, in addition to the training of workers, measures of wealth distribution, including the establishment of welfare networks, underlining the importance of minimum income.

At any rate, the main question that interests us here has the following treatment in the mainstream scholarly discourse: the technological progress related to Industry 4.0 will probably lead the economy towards deterioration in wage distribution and worse conditions of employability for many workers. To grapple with this situation, the most important action would be to educate workers so they could thrive in a digital and automated future, accessing occupations in sectors of high productivity and wages. This is the predominant narrative, where, occasionally, less optimist readings make concessions to the use of public policies to deal with excessive inequality in the short and medium terms.

Here we must point that despite its prevalence this narrative is not easily sustained if confronted with some current facts of manufacturing. The section 1 of this article already mentioned the lack of evidence of any vigorous productivity gain provided by the machinery recently implemented in the U.S. (Sprage, 2021, April), as well as the controversies regarding the idea that a revolutionary "machine age" would be upon us. If we look a little longer into the relevant data, other aspects of the matter present themselves in a much less straightforward way than the mainstream reading supposes. The connection between inequality and technological advancement is not easy to track, for instance – especially if we make international comparisons.

Specifically, the Chinese case also does not fit well in this narrative. The country's industry has thoroughly progressed in its complexity and productivity in the last years. However, the raising automation of China's manufacture has gone side-by-side with wage growth and inequality reduction, even if the working force does not seem to have been through

[6] To illustrate, Atkinson (2018, February) is particularly prolific in suggestions of workforce training to the United States.

any proportional training.[7] Moreover, automation is spreading throughout global industry, but it is not easy to find any correlation between inequality indexes and the use of robots. If we look at the World Bank data, the Gini coefficient in China deteriorated heavily between 1990 and 2010, improving afterwards – exactly when robot use progressed. In this regard, it seems interesting to compare the countries with highest robot density[8] and the recent evolution of their Gini coefficients, as Table 1 shows:

Table 1. Roboty density x Gini coefficient

Country	Roboty density (Robots per 10,000 employes)	Gini coefficient
Republic of Korea	868 (2019)	0.317 (2006) 0.314 (2016)
Japan	364 (2019)	0.348 (2008) 0.329 (2013)
Germany	346 (2019)	0.303 (2001) 0.319 (2016)
Sweden	274 (2019)	0.272 (2000) 0.300 (2018)
Denmark	243 (2019)	0.238 (2000) 0.282 (2018)
Hong Kong	242 (2019)	0.530 (2001) 0.540 (2016)
USA	228 (2019)	0.406 (2001) 0.414 (2018)
China	187 (2019)	0.420 (2002) 0.385 (2016)
Brazil	13.6 (2017)	0.584 (2001) 0.539 (2018)

[7] The average wage in the Chinese industry has trebled between 2008 and 2018 (Statista, n.d.), but it is difficult to see any proportional gain in workers' education in the period.

[8] The robot density estimates refer to 2019 and come from the International Federation of Robotics (IFR, 2021), except the data from Brazil, which refers to 2017. The country with biggest robot density is Singapore; however, considering the country's size and its lack of Gini data, it was not added to our Table.

The majority of countries listed above have indeed witnessed a slight worsening in their Gini coefficients in the past decades, particularly when compared with the inequality levels of the 1980s or mid-1990s. However, looking at the figures comparatively, we cannot see a straightforward relation between countries' inequality and their level of industry automation, which is our focus here – and the reason why Table 1 contains data form the beginning of the century and the most recent figure available. More interestingly, Japan and Korea, the economies with highest robot density, underwent a reduction in inequality in the period with data available. At the same time, Germany, Hong Kong and the U.S. have not presented any substantial variation in their indexes, while Nordic countries have maintained reasonably equal societies. At any rate, the U.S. has presented worse inequality coefficients than present-day Europe since the 1970s, and Brazil, not particularly endowed with a dynamic industry, has seen its Gini coefficient stand above the (high) 0.5 level, notwithstanding its educational progress in the period.

Even if we raise questions on the use of the Gini coefficient to this analysis, any other consistent studies on inequality, like Piketty's (2013 and 2019), do not find a direct and significant correlation between this variable and manufacturing automation.[9] Therefore, there is evidence that the mainstream analysis of productive changes does not treat properly some current facts in the international economy. Having recognized that, if we want to understand the challenges that labor will face in the twentieth-first century, a critical appraisal of the more orthodox literature on the matter is overdue.

3. An alternative approach to the issue

3.1. Criticism to the predominant view: a historical reading

Amid the studies and reports reviewed in section 2, the most controversial were those that tried to estimate the number of jobs and occupations to be eliminated due to the expansion of Industry 4.0. A first line of criticism that can be directed at them is quite obvious, and in some cases the authors themselves evoke it: basing their work in static analysis, they end up making estimates solely on the present occupational matrix. We have to admit that this stands for a rather limited scope, because such exercises simply ignore that the occupational matrix under a technological shock will be transformed, creating new occupations. Therefore, if we want to have a plausible glimpse into the future, estimating the quantity of jobs to be lost due to technological change is not enough. We need an assessment of the occupations that this same change will create.

[9] From another theoretical perspective, Shaikh (2016) also points that wages and productivity do not keep important correlation, questioning the idea that inequality could be due to differences in automation or workers' capabilities.

Moreover, the technical possibility of substituting human labor for robots does not mean that the substitution will necessarily occur. Only an economic evaluation at a specific moment will determine if there will be job losses in each firm. Most researchers are aware of this and try to build their predictions on practical market knowledge.[10] However, it is not possible to assure the accuracy of their assumptions on technological advancement[11] and prices. Concerning their time frame, they are so imprecise that the period expected for changes to take place in Frey and Osborne (2013) is intentionally vague, and may extend for four decades in MGI (2017). This poses a big problem if we consider that the timing of technical modifications is one of the most important factors to determine the cost of adjustment (in terms of unemployment and wage cuts) in mainstream models.

The lack of international context in the reviewed studies must also be underlined as one of their major shortcoming. After all, we are dealing with a phenomenon regarding structural technological change in a global industry based on competitive value chains. The estimates on the studies reviewed above, however, focus mostly on national productive matrixes. This is a serious limitation since the competition of international industry is of utmost importance to determine the conditions of existence for any manufacturing activity. In the case of Industry 4.0, the competition of East Asian firms that are developing new machinery may lead to the displacement of western manufacturers and the elimination of jobs they provide. Obviously, it is difficult to have any evaluation of the impact of stronger international competition on the current structure of production. Nevertheless, a big disclaimer regarding this fault should be added to those studies, helping their readers reckon that the figures presented in them are not very reliable indicators of the changes that will happen in the labor market in the next decades.[12]

In the same vein, if we question the mainstream assumption that wages are a direct function of workers' marginal productivity and treat them instead as generally depending on the jobs supply, the diminishing importance of industrial occupations in western countries could still be liable for the growing inequality – but there would be no reason to

[10] Frey and Osborne (2013), for example, organized a workshop with sectorial specialists so they could determine the occupations with higher automation probability; MGI (2017), in its turn, called industry specialists and executives to base their predictions on.

[11] In this regard, Pfeiffer (2017) argues that Frey and Osborne (2013) and other studies inspired by them have a bias towards underestimating workers' capabilities. Currently, the tasks of industrial workers are diverse and complex, but those studies tend to consider any human activity performed with the help of machines as simple routine – and, therefore, easy to substitute.

[12] At any rate, it should be highlighted that the very idea of a radical change in production makes these prediction exercises intrinsically problematic. As argued by Pfeiffer (2017, p. 111), "simple logical reasoning also cautions us to be skeptical. If we take the discourse's claim of immanent 'revolutionary' and 'disruptive' developments at face value, we actually have zero basis to make robust predictions of future events."

consider it technology's fault. The ascendancy of manufacturing in East Asia in the past decades should be enough to make this point. China is pivotal to the new international scenery, since the country is now home to approximately 25% of global industry output – while in the beginning of 1970s this figure was around 1% (Morceiro & Tessarin, 2019). If manufacturing has offshored this much of its production to China, it is clear that most of the jobs followed suit, independently of any machinery use back home. The firms moved to China in search of cost (especially wage) reductions, and downsized their industrial output in their older western plants. Qualified jobs in the latter became scarcer, and wages were put under a tendency of reduction or stagnation. Notwithstanding, the inequality provoked by this movement cannot be attributed to the technological advancement in any way.

Furthermore, in the last four decades China has passed from being a textile exporter to being the world's workshop. In this process, the country has developed high-end technology in some sectors, expanding the ratio of its workers on manufacturing (29% in 2017, compared to 21.5% in 1991).[13] This high industrial investment came mostly from transnational companies, which in 2009 were responsible for 85% of Chinese high technology production destined to export (Hart-Landsberg, 2015).

Paying attention to this context, we see that in the very period productivity has detached from wages in the core capitalist economies, we have also witnessed the latter's transnationals companies investing in massive Chinese low-wage production. In the process, China has made approximately one billion workers available to the international capital (The Economist, 2012, January 23), creating a pressure (even if indirect) on labor's bargain power in the most advanced economies. Therefore, it seems clear that the production's offshoring to East Asia has had an important role in the relative wage squeeze in the center of the capitalist system. The international political context suitable to the liberalization of markets is, thus, mostly accountable for growing inequality. This reading of the facts corroborates the post-Keynesian thesis, which states that wages are determined by political and institutional factors, and do not follow labor's marginal productivity (Stockhammer, 2020).

At this point, it is interesting to remember that the correlation between the wage-productivity detachment and technological progress has already been considered problematic in other contexts. Brynjolfsson and McAfee (2014) show that the detachment between wages and productivity begins in the 1973-1974 crisis, growing stronger since then. The authors try to correlate this phenomenon with the expansion of computer use into the industrial structure. However, as they state themselves, it is not possible to identify any considerable use of

[13] To draw a comparison: U.S. had approximately 19.9% of its workers employed in manufacturing in 2019, whilst Germany had 27.2%. In 1991, the figures were 26.0% and 37.7%, respectively (World Bank, n.d.).

computing in industry before the mid-1980s. Actually, the massive use of computers in industry could only be noticed at the beginning of the 1990s.[14] Consequently, it has arrived a little too late to serve as an explanation for the U.S. inequality. This gap, like the data presented in Table 1, should caution us about the risks involved in easily accepting the idea that unequal appropriation of productivity in the recent past was due to the lack of training of the workforce. Looking at the mentioned facts, it seems more legitimate to connect this phenomenon with the liberalization of markets and the industry offshoring to East Asia.

Considering this, it seems that the main problem in the studies reviewed is the model implied in their analysis of the labor market. In broad lines, they implicitly adopt the hypothesis of substitution between factors of production and flexibility in real wages. In so doing, they naturally assume a tendency to "full employment" in the economy, and any unemployment or inequality stems from the workers' characteristics (i.e. they do not have the needed capabilities) or their inefficient "corporations" (trade unions) or government inept policies (i.e. minimum wage). In this orthodox reasoning, all unconstrained labor supply will create its own demand, and will be remunerated according to its marginal productivity. In addition to using this less than obvious relation between productivity and wages as a pillar,[15] these models ignore the institutional and international details that make the seizure of productivity gains by workers a complicated matter.[16] Nevertheless, if we re-evaluate this analytical framework, the "job polarization" may be understood as the byproduct of modifications in the socioeconomic structure, amongst which the change in the macroeconomic regime, the liberalization of international markets and the loss of labor's bargain power stand out – phenomena which were, by the way, clearly originated in the mid-1970s.

We face, therefore, a structural problem in the models used to analyze labor markets in the reviewed literature. Its shortcomings are not restricted to the imprecision of figures on job losses. Substantially, they all imply a dynamics of labor and capital allocation based on the substitution of factors and price flexibility, which entails theoretical and empirical ambiguities.[17] In this framework, adjustment problems are usually left to the spirit of the

[14] As Solow (1987, July 12, p. 36) stated in the 1980's, "you can see the computer age everywhere but in the productivity statistics".

[15] Lavoie (2014) and Lavoie and Lang (2018) present with more detail the problems in the orthodox assessment of labor market, which erroneously equates wages to marginal productivity.

[16] Paul (2018) presents the difficulties put by contemporary institutions on the transfer of productivity gains to the workers.

[17] It is important to highlight the existence of a long and profound debate over the theoretical fragility of the economic mainstream, which postulates the full employment of resources and its respective remuneration according to their marginal productivity (Lazzarini, 2011). Moreover, to accept the assumption of high competition made in the mainstream models seems especially unrealistic when

study's author, as they see with more or less optimism the outcome of market frictions provoked by the use of new machinery. It must be said, firstly, that this lack of precision is a byproduct of the absence of evidence that Industry 4.0 bears radical changes: if we cannot foresee which are the new machines, where they will be used and when, it all becomes a matter of educated guesses on these issues and on the respective labor market response. But secondly, and more important to the point here, this guessing is only accepted as scientific evidence because it subscribes to a particular model which has been naturalized despite its flaws to explain how wages and unemployment are determined in present day capitalist economies.

In this sense, it would be interesting to question whose interests are served by the adoption of the consensus that a fourth industrial revolution is on the making, and its "natural" market results would be wage distribution deterioration. The corollary of this idea, i.e. that inequality can only be confronted with workforce education – and not resorting to any kind of radical structural change – is clearly interesting for some social classes controlling Industry 4.0 financing and production. That is probably the origin of the mainstream's influence on the theme and why, notwithstanding its inconsistencies, it keeps a remarkable political strength, as we may see in IMF (2018), OECD (2018), and CEPAL (2017).[18]

Nevertheless, as most of the orthodoxy will concede, we have a shared past where market and institutional conditions have contributed to the incorporation of technology and workforce to the productive structure with wage gains and low inequality – at least in the most developed capitalist countries. If we want to see this dynamic in operation once again, we must understand which forces pressured businesses into transferring productivity gains to wages. After all that we have argued, it seems obvious that we must seek an alternative to the mainstream model to do so.

3.2. An alternative theoretical structure

In order to understand how high levels of employment and wage coexisted with technological development in western countries, especially between 1950 and 1980, it seems logical to examine this period using the models that were the pillars of the policies adopted in that "golden age" of capitalism. Therefore, dwelling on the importance of the effective demand

treating the industrial structures built during the twentieth century – an era of global markets domination by transnational conglomerates. It is never enough to underline the pivotal role of public institutions to innovation (Mazzucato, 2014), and the power of trade unions in this rather progressive era of capitalism.

[18] Krugman (2021, April 15) makes a similar point, stressing how comfortable it is for certain classes the "centrist escapism" of suggesting education will solve some economic problems.

is inevitable, since this principle, as postulated by Keynes (1936), was of foremost significance for economic policies in the "*trente glorieuses*".

It is widely acknowledge that Keynes, when developing the concept of effective demand, approached production and employment levels as consequences of the conditions on real-goods markets. In this manner, he saw investment and consequently unemployment dependent on the level of total expenditure of the society. From this point of view, any negative turn of the economy's growth (and raise in unemployment) should be reversed by a stimulus to the autonomous expenditure, normally through government expending. The demand thus created would prompt the conditions for its own sustainability.

This reasoning is usually the basis for short-term stimulus policies, but it could be seen as valid in the long-term. After all, if we consider that the economy is continuously going through changes provoked by technical enhancement, and that such enhancement brings about instability in labor and capital markets, including involuntary unemployment, we can assume that aggregate demand management is a tool to deal with unemployment and income level in longer terms (Cesaratto, Serrano, & Stirati, 2003; Lavoie, 2014). As argued by Keynes (1936) and Kalecki (1954), there is no reason for an economy freely operating to find itself in full employment. Hence, the use of autonomous expenditure must be a constant concern of the economic policy.

Within this framework, the quantity of jobs in a given economy follows the macroeconomic policy directions to effective demand, considering the institutional and international constraints. It does not seem a coincidence, thus, that the years between 1950 and 1980, when low unemployment and technological progress walked hand-in-hand, were also years when policies of demand stimulus were predominant, following the Keynesian prescription.

Institutions from this era also kept a relatively egalitarian income distribution (Piketty, 2013 and 2019), but they were submitted to heavy attack when the economic expansive cycle which had begun in the aftermath of World War II lost its impetus in the 1970s. We cannot develop the reasons for that slowdown here; it is enough to point that the U.S. responded to that context with a new policy for the dollar, which put an end, in practical terms, to the monetary system of Bretton Woods (Tavares, 1997).[19] The neoliberal conception of macroeconomic management then started to build its global hegemony. A few years later, when the Soviet Union disappeared and the cold war reached an end, the liberalization was reinforced in the international arena, with heavy impacts in labor markets around the world –

[19] The Bretton Wood system worked approximately how Keynes had idealized it after World War II thanks to the Cold War and the communist threat, which induced the U.S. to adopt policies that provided its allies with currency, allowing their growth with high employment. This context was advantageous to the working class, and served the income distribution (Medeiros & Serrano, 1999).

the most clear being the loss of power of worker's unions. This same liberalization reached international financial flows, which found no barrier to invest in production in East Asia – with emphasis on China, which began its integration to the capitalist system following a political and economic plan from the U.S. (Medeiros, 1999).

As discussed above and pointed by Mishel and Bivens (2017, May 24), low Asian wages combined with general liberalization ended up favoring production offshoring to Asia. This entailed layoffs in western manufacturing, which weakened trade unions and workers' bargain power. With no other options, many of these unemployed turned to the service sector in search of jobs – which they most likely found, but with lower wages. The inequality and precarious working conditions that have spread throughout the globe during the last years have originated, therefore, on the adoption of a specific macroeconomic regime in various countries, following a hierarchy mediated by international institutions. The advancement of Artificial Intelligence or robots do not seem to play any major role in this process.[20]

Of course, automation may eliminate more jobs than it creates in specific sectors, but in a modern capitalist economy that should not directly translate into higher unemployment or job polarization – simply because the government can always use its capacity of expenditure to assure that unemployment will stay within a determined threshold. That is why the experience of industrial expansion with technological and social progress after World War II is actually a story of governmental planning and intervention (Chang, 2009; Cohen & De Long, 2016). If there is no reason for any unregulated and free economy to direct itself to full employment, growth in occupational level and wages had to be the outcome of policies that reinforced aggregated demand and, consequently, demand for labor. In this perspective, technological advancement has no specific effect on wages and unemployment – it is just another disequilibrium factor in the capital accumulation dynamic, which depends on the management of the effective demand to continue without major crisis anyway.

Therefore, if History is to serve as any guide, expansive monetary and fiscal policies are more important to attain full employment and dwindle inequality than training workers. Such policies would impel aggregated demand and allow for redistribution of wealth. Of course, workers' education and capabilities building would still have importance in reaching higher productivity in any given economy. However, this is a secondary point in a process that is

[20] Coveri and Pianta (2019) empirically corroborate this. Using data from the European Industry between 1994 and 2014, they find a negative correlation between wages and innovation in capital goods. Notwithstanding, the same negative effect on wages stems from production offshoring and low levels of unionization – which, by the way, raise profits. Western and Rosenfeld (2011) also present clear correlation between the loss of trade unions' power and wage inequality in the US.

ultimately dependent on the demand. After all, we may educate workers, but without demand for their new capabilities, they may simply end up unemployed.

Final considerations

The present article has built a critical assessment of the literature on Industry 4.0 impacts on labor market. In broad lines, we concluded that the predominant views on the debate tend to overlook institutional and structural conditions that influence aggregate demand and investment – the most important determinants of unemployment and wages. Historically, it seems clear that it was the management of these two variables that allowed technological progress and expansion of jobs to be associated with better wage distribution in the capitalist system.

This reading of the facts suggests that training the workforce to face a new industrial era is not enough to decrease unemployment or reduce "job polarization". On the contrary, it exposes the need to search for alternative economic policies to address these problems. If we treat the question as one of finding a level of national supply and demand that is compatible with full employment and social welfare, the limitations of repeatedly standing for labor training become obvious. The quantity of jobs in a given economy is a direct function of the demand for goods and services. This fact has not changed since the 1930s, when Keynes wrote his opus. The same can be said of the capital accumulation dynamic, which is still the same and, left to itself, is likely to produce inequality and unemployment.

The modifications in the productive matrix linked to the technical development of Industry 4.0 will surely demand new capabilities from the workforce. However, if inequality and unemployment are currently identified as major social problems, this has little connection with technology. When choosing to turn the spurious correlation between inequality (or unemployment) and technical progress into one of the most important economic debates of our time, the mainstream studies reviewed above neglect pressing questions that need to be addressed if we want to tackle those problems: the macroeconomic policy and its international context.

In practical terms, if labor training is not followed by a demand of their capabilities – which implies investment – the newly qualified workers will simply end up reinforcing the "unlimited supply of labor" mentioned by Lewis (1954) in strata that are more educated. This situation would entail a growing number of workers with complex capabilities unable to use them and constrained to dispute a job wherever they can find one, putting a pressure towards wage squeeze in the whole economy.

Overall, the most important message from this article is that we need to question the logical assumptions of the currently predominant economic theory. As it stands today, the mainstream model sees no problem in leaving the burden of structural adjustment to the labor force and its training. However, there are many economic policies more suitable to dealing with inequality and unemployment. These policies do not depend on revolutionary or innovative concepts. They can be based on theories and experiences of the twentieth century, when many countries combined technological progress, low unemployment, wage raise and low inequality. If there are still doubts on the revolutionary character of Industry 4.0, much more stands in the way of considering it a novelty regarding the problems it raises for economic policy. Clearly, Industry 4.0 does not need an "Economic Theory 4.0". A good understanding of the basics of effective demand should do the trick.

References

Acemoglu, D. (2019, June). It's good jobs, stupid. [Research Brief], Economics for Inclusive Prosperity. https://econfip.org/policy-brief/its-good-jobs-stupid/

Acemoglu, D., & Restrepo, P. (2017). Robots and jobs: Evidence from US labor markets. [NBER Working Paper Series, No. 23285], National Bureau of Economic Research. https://doi.org/10.3386/w23285

Allen, R. C. (2017). Lesson from History for the future of work. *Nature*, *550*, 321–324. https://doi.org/10.1038/550321a

Andreoni, A., Chang, H., & Labrunie, M. (2021). Natura non facit saltus: challenges and opportunities for digital industrialization across developing countries. *The European Journal of Development Research*, *33*, 330–370. https://doi.org/10.1057/s41287-020-00355-z

Arntz, M., Gregory, T., & Zierahn, U. (2016). The risk of automation in OECD countries: a comparative analysis. [OECD Social, Employment and Migration Working Papers, No. 189], OECD Publishing. https://doi.org/10.1787/5jlz9h56dvq7-en

Atkinson, R. (2018, February). How to reform worker-trainig and adjustment policies for an era of technological change. [Innovation Employment Workforce Policies] Information Technology and Information Foundation (ITIF). http://www2.itif.org/2018-innovation-employment-workforce-policies.pdf?_ga=2.256883275.1536983798.1584889880-332537106.1584889880

Autor, D. (2015). Why are there still so many jobs? The History and future of workplace automation. *Journal of Economic Perspectives*, *29*(3), 3–30. http://dx.doi.org/10.1257/jep.29.3.3

Autor, D., Levy, F., & Murnane, R. (2003). The skill content of recent technological change: an empirical exploration. *The Quarterly Journal of Economics*, *118*(4), 1279–1333. https://doi.org/10.1162/003355303322552801

Berg, A., Buffie, E., & Zanna, L.-F. (2018). Should we fear the robot revolution? (The correct answer is yes). [IMF Working Paper, No. 18/116], International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2018/05/21/Should-We-Fear-the-Robot-Revolution-The-Correct-Answer-is-Yes-44923

Bernstein, A. & Raman, A. (2015, June). The great decoupling: an interview with Erik Brynjolfsson and Andrew McAfee. *Harvard Business Review*. https://hbr.org/2015/06/the-great-decoupling

Brynjolfsson, E., & Mcaffe, A. (2014). *The second machine age: Work, progress and prosperity in a time of brilliant technologies*. W.W. Norton & Company.

Cesaratto, S., Serrano, F., & Stirati, A. (2003). Technical change, effective demand and employment. *Review of Political Economy*, *15*(1), 33–52. https://doi.org/10.1080/09538250308444

Chang, H. J. (2009). *Maus samaritanos: O mito do livre-comércio e a história secreta do capitalismo*. Elsevier.

Cohen, S. & De Long, B. (2016). *Concrete economics: The Hamilton approach to economic growth and policy*. Harvard University Press.

Comisión Económica para América Latina y el Caribe (CEPAL) (2017). *Políticas industriales y tecnológicas en América Latina*. Editado por M. Cimoli, M. Castillo, G. Porcile, & G. Stumpo. Naciones Unidas. https://www.cepal.org/es/publicaciones/42363-politicas-industriales-tecnologicas-america-latina

Coveri, A. & Pianta, M. (2019). Technology, profits and wages. [LEM Working Paper Series, 2019/35], Laboratory of Economics and Management, Scuela Superiore Santa'Anna, Italy. http://www.lem.sssup.it/WPLem/2019-35.html

Daudt, G., & Willcox, L. D. (2016). Reflexões críticas a partir das experiências dos Estados Unidos e da Alemanha em manufatura avançada. *BNDES Setorial*, (44), 5–45. https://web.bndes.gov.br/bib/jspui/handle/1408/9936

Estolatan, E., Geuna, A., Guerzoni, M., & Nuccio, M. (2018). Mapping the evolution of the robotics industry: a cross country comparison. [LEI & BRICK Working Paper, 5/2018], Department of Economics and Statistics "Cognetti de Martiis", Italy. https://www.est.unito.it/do/home.pl/Download?doc=/allegati/wp2018dip/wp_12_2018.pdf

Frey, C., & Osborne, M. (2013). The future of employment: how susceptible are jobs to computerisation? [Oxford Martin School Working Paper, September 17, 2013], University of Oxford. https://www.oxfordmartin.ox.ac.uk/downloads/academic/future-of-employment.pdf

Goos, M., & Manning, A. (2003). Lousy and lovely jobs: the rising polarization of work in Britain. [Center for Economic Performance Discussion Papers, DP0604], London School of Economics and Political Science. https://cep.lse.ac.uk/pubs/download/dp0604.pdf

Hart-Landsberg, M. (2015). From the claw to the lion: a critical look at capitalist globalization. *Critical Asian Studies*, *47*(1), 1–23. https://doi.org/10.1080/14672715.2015.997024

Hermann, M., Pentek, T., & Otto, B. (2015). Design principles for industrie 4.0 scenarios: a literature review. [TU Working Paper, No. 01/15]. Technische Universität Dortumund. https://doi.org/10.13140/RG.2.2.29269.22248

International Federation of Robotics (IFR) (2021). Robot race: The world's top 10 automated countries. https://ifr.org/ifr-press-releases/news/robot-race-the-worlds-top-10-automated-countries

International Monetary Fund (IMF) (2018). *World Economic Outlook 2018*. https://www.imf.org/en/Publications/WEO/Issues/2018/03/20/world-economic-outlook-april-2018

Kalecki, M. (1954). *Theory of cconomic dynamics: an essay on cyclical and long-run changes in capitalist economy*. George Allen and Unwin.

Keynes, J. M. (1936). *The general theory of employment, interest and money*. Cambridge University Press.

Krugman, P. (2021, April 15). Andrew Yang hasn't done the Math. *The New York Times*. https://www.nytimes.com/2021/04/15/opinion/andrew-yang-automation.html

Lavoie, M. (2014) *Post-keynesian economics: New foundations*. Edward Elgar.

Lavoie, M., & Lang, D. (2018). Les déterminants du niveau de l'emploi. In E. Berr, V. Monvoisin, & J. Ponsot (Eds.), *L'économie post-keynesienne: Histoire, théorie et politiques*. Seuil.

Lazzarini, A. (2011). *Revisiting the Cambridge capital theory controversies: a historical and analytical study*. Pavia University Press.

Lewis, W. (1954). Economic development with unlimited supplies of labour. *The Manchester School*, *22*(2), 139-191. https://doi.org/10.1111/j.1467-9957.1954.tb00021.x

Martinelli, A., Mina, A., & Mogi, M. (2019). The enabling technologies of Industry 4.0: examining the seeds of the fourth industrial revolution. [LEM Working Paper Series, 2019/09], Laboratory of Economics and Management, Scuela Superiore Santa'Anna, Italy. https://ideas.repec.org/p/ssa/lemwps/2019-09.html

Mazzucato, M. (2014). *O Estado empreendedor: Desmascarando o mito do setor público vs. setor privado*. Portfólio-Penguim.

McKinsey Global Institute (MGI) (2017). *A future that works: Automation, employment, and productivity*. Edited by J. Manyika, M. Chui, M. Miremadi, J. Bughin et al. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Full-report.ashx

Medeiros, C. (1999). China: entre os séculos XX e XXI. In J. L. Fiori (Org.), *Estados e moedas no desenvolvimento das nações*. Vozes.

Medeiros, C., & Serrano, F. (1999). Padrões monetários internacionais e crescimento. In J. L. Fiori (Org.), *Estados e moedas no desenvolvimento das nações*. Vozes.

Mishel, L., & Bivens, J. (2017, May 24). The zombie robot argument lurches on. [Report] Economic Policy Institute. https://www.epi.org/publication/the-zombie-robot-argument-lurches-on-there-is-no-evidence-that-automation-leads-to-joblessness-or-inequality/

Morceiro, P., & Tessarin, M. (2019). *Desenvolvimento industrial em perspectiva internacional comparada*. Instituto de Estudos para o Desenvolvimento Industrial (IEDI). https://iedi.org.br/media/site/artigos/20190802_desind_intern_comp.pdf

Morgan, J. (2019). Will we work in twenty-first century capitalism? A critique of the fourth industrial revolution literature. *Economy and Society*, *48*(3), 371–398. https://doi.org/10.1080/03085147.2019.1620027

Organisation for Economic Co-operation and Development (OECD) (2015). Enabling the next production revolution: issues paper. [DSTI/IND, 2015-2], Directorate for Science, Technology and Innovation, Committee on Industry, Innovation and Entrepreneurship, OECD. https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DSTI/IND(2015)2&docLanguage=En

Organisation for Economic Co-operation and Development (OECD) (2018). Transformative technologies and jobs of the future. [Background report for the Canadian G7 Innovation Ministers' Meeting], Montreal, Canada, 27-28 March 2018. https://www.oecd.org/innovation/transformative-technologies-and-jobs-of-the-future.pdf

Oztemel, E. & Gursev, S. (2018). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, *31*, 127–182. https://doi.org/10.1007/s10845-018-1433-8

Paul, M. (2018). *Don't fear the robots: Why automation doesn't mean the end of work*. Durham, NC: The Roosevelt Institute and The Samuel Dubois Cook Center on Social Equity. https://rooseveltinstitute.org/wp-content/uploads/2020/07/RI-Don%E2%80%99t-Fear-the-Robots-201806.pdf

Pfeiffer, S. (2017) The vision of "Industrie 4.0" in the making – a case of future told, tamed, and traded. *NanoEthics*, *11*, 107–121. https://doi.org/10.1007/s11569-016-0280-3

Piketty, T. (2013). *Le capital au XXIème siècle*. Seuil.

Piketty, T. (2019). *Capital et idéologie*. Seuil.

Schwab, K. (2016). *The fourth industrial revolution*. Crown Business.

Shaikh, A. (2016). *Capitalism: competition, conflict, crises*. Oxford University Press.

Solow, R. (1987, July 12). We'd better watch out. *The New York Times Book Review*. http://www.standupeconomist.com/pdf/misc/solow-computer-productivity.pdf

Sprage, S. (2021, April). The U.S. productivity slowdown: an economy-wide and industry-level analysis. *Monthly Labor Review*, U.S. Bureau of Labor Statistics. https://doi.org/10.21916/mlr.2021.4

Statista (n.d.). Average yearly wages in the manufacturing sector in China from 2008 to 2018. https://www.statista.com/statistics/743509/china-average-yearly-wages-in-manufacturing/

Stockhammer, E. (2020). *Post-keynesian macroeconomic foundations for comparative political economy*. [PKES Working Paper No. 2022], Post-Keynesian Economic Society. http://www.postkeynesian.net/downloads/working-papers/PKWP2022.pdf

Tavares, M. C. (1997). A retomada da hegemonia norte-americana. In M. C. Tavares, & J. L. Fiori (Org.), *Poder e dinheiro: Uma economia política da globalização*. Vozes.

The Economist (2012, January 23). One billion workers. https://www.economist.com/free-exchange/2012/01/23/one-billion-workers

Weller, J., Gontero, S., & Campbell, S. (2019). Cambio tecnológico y empleo: una perspectiva latinoamericana. Riesgos de la substitución tecnológica del trabajo humano y desafíos de la geración de nuevos puestos de trabajo. [Serie Macroeconomía del Desarrollo, No. 201], CEPAL. https://www.cepal.org/es/publicaciones/44637-cambio-tecnologico-empleo-perspectiva-latinoamericana-riesgos-la-sustitucion

Western, B., & Rosenfeld, J. (2011). Unions, norms, and the rise in U.S. wage inequality. *American Sociological Review*, *76*(4), 513–537. https://doi.org/10.1177/0003122411414817

World Bank (n.d.). Employment in industry (% of total employment) (modeled ILO estimate). https://data.worldbank.org/indicator/SL.IND.EMPL.ZS

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