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Efeitos das novas tecnologias de manufatura no emprego: por que não temê-los e como gerenciá-los

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Resumo: Este artigo questiona a narrativa emergente de que novas tecnologias de manufatura reduzem o papel da manufatura na criação de empregos e no desenvolvimento econômico. Com base em estudos empíricos recentes, argumentamos que as evidências sobre os efeitos no emprego estão longe de serem conclusivas e, frequentemente, apontam ganhos líquidos de postos de trabalho, especialmente em países em desenvolvimento. Os efeitos sobre o emprego variam significativamente de acordo com fatores como o tipo de tecnologia adotada, a estrutura industrial em que ela é introduzida e as condições prevalentes no mercado de trabalho, não sendo, portanto, passíveis de generalização. Além disso, estudos de previsão que projetam grandes perdas de empregos devido à automação costumam apresentar falhas conceituais, focando na viabilidade técnica das novas tecnologias e negligenciando sua viabilidade econômica e sociopolítica, bem como os potenciais de criação de novos postos de trabalho. Para ilustrar a complexidade dessas dinâmicas, examinamos um subconjunto de tecnologias digitais de produção, destacando que seu impacto mais significativo muitas vezes se concentra na melhoria do controle, da eficiência e da velocidade de produção, em vez de simplesmente reduzir custos de mão de obra. Ademais, mostramos que as preocupações acerca de um declínio global do emprego na manufatura carecem de respaldo empírico, refletindo em grande medida a transferência de empregos industriais de economias ocidentais para países em desenvolvimento, em particular na Ásia. Essas diferenças regionais ajudam a explicar a preocupação em nações desenvolvidas com o suposto declínio da manufatura. Por fim, apresentamos estudos de caso históricos sobre políticas trabalhistas bem-sucedidas em períodos de grandes transições tecnológicas, salientando que a segurança no emprego—tanto no nível da empresa quanto em toda a economia—desempenha papel crucial na criação de um ambiente receptivo à inovação. Esta pesquisa ressalta a necessidade de investigações adicionais sobre como equilibrar o avanço tecnológico com o bem-estar social, garantindo que a manufatura continue sendo um motor viável de desenvolvimento.

Palavras-chave: Emprego na manufatura; Novas tecnologias; Desenvolvimento industrial; Política trabalhista; Automação.

Código JEL: O14, J21, L60

Área Temática: 10.1 Novas tecnologias e impactos sobre o emprego

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Employment effects of new manufacturing technologies: why not to fear them, and how to manage them

Abstract: This paper challenges the emerging narrative that new manufacturing technologies diminish manufacturing's role in job creation and economic development. Drawing on recent empirical studies, we argue that the evidence on employment effects is far from conclusive and often suggests net job gains, especially in developing countries. Employment effects vary widely based on factors such as the type of technology adopted, the industrial structure in which it is introduced, and prevailing labour market conditions, and thus cannot be generalised. Furthermore, forecasting studies that predict massive job losses due to automation frequently present conceptual flaws and focus on the technical feasibility of new technologies, neglecting economic and socio-political viability and overlooking potential job-creating avenues. To further illustrate the nuance of these employment dynamics, we examine a subset of digital production technologies, emphasizing that their most significant impact often lies in enhancing production control, efficiency, and speed, rather than merely cutting labour costs. Moreover, we show that concerns about a global decline in manufacturing employment lack empirical backing, and largely reflect a shift of industrial jobs from Western economies to developing, particularly Asian, countries. These regional differences help explain the preoccupation in developed nations with manufacturing's perceived decline. Finally, we provide historical case studies of successful labour policies during major technological transitions, highlighting that employment security—whether at the firm or economy-wide level—plays a pivotal role in fostering a receptive climate for innovation. This research underscores the need for continued inquiry into how best to balance technological advancement with social welfare, ensuring that manufacturing remains a viable engine of development.

Keywords: Manufacturing employment; New technologies; Industrial development; Labour policy; Automation

*“I do not fear computers.
I fear the lack of them”*
– Isaac Asimov

1 Introduction

Several authors recently raised concerns about a potential reduction in the manufacturing sector’s capacity to generate jobs. This is often attributed to the fact that manufacturing industries today would be using labour-saving technologies, especially digital ones, and thus would not be able to absorb the same amount of workers as they did in the past. Based on this, these authors challenge the importance of manufacturing in the economy and question the desirability of industrialisation for developing countries. For example, Baldwin and Forslid in their paper “When Manufacturing is Jobless and Services are Tradeable” (BALDWIN; FORSLID, 2020) argue that:

“A growing body of evidence has begun to challenge the view that manufacturing is the prime route for development (...). First, many of the pro-development characteristics traditionally associated with manufacturing—tradability, scale, innovation and learning-by-doing—are increasingly features of services (...). Other aspects of digital technology (‘digitech’) are changing the nature of manufacturing by replacing the ‘manu’ with robots, so that we now speak of ‘robofacturing’, (...). Taken together, these aspects of globotics are pulling the rug from under traditional development strategies that equates development with industrialization. While nations may still export robofactured goods, these sectors will be more like oil wells that create value and exports but few jobs.” (p. 1)

Similarly, a World Bank report named “Trouble in the making? The future of manufacturing-led development” (HALLWARD-DRIEMEIER; NAYYAR, 2017) questions development strategies based on manufacturing:

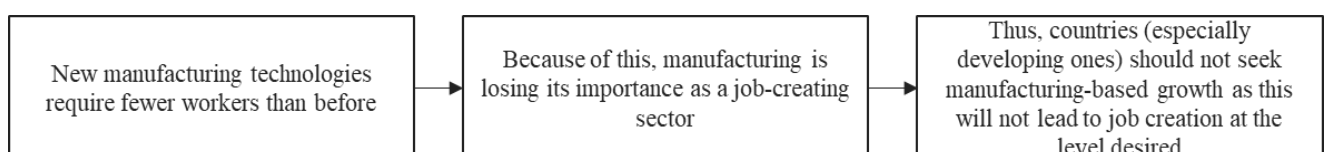
“In the past, manufacturing-led development typically delivered both productivity gains and job creation for unskilled labor. (...) Looking ahead, changing technologies and shifting globalization patterns call the feasibility of manufacturing-led development strategies into question. Trade is slowing. Global value chains (GVCs) remain concentrated among a relatively small number of countries. The Internet of Things, advanced robotics, and 3-D printing are shifting the criteria that make locations attractive for production and are threatening significant disruptions in employment, particularly for low-skilled labor. These trends raise fears that manufacturing will no longer offer an accessible pathway for low-income countries to develop and, even if feasible, would no longer provide the same dual benefits of productivity gains and job creation for unskilled labor.” (p. 1)

Dani Rodrik, a highly influential scholar, also cast doubts on manufacturing’s potential for creating good jobs in developing countries in his op-ed named “Poor Countries’ Technology Dilemma”:

“There’s a rub, however, in Africa’s manufacturing renaissance. Even where industrialization is putting down deeper roots, few good jobs have been created in the more modern, formal, and productive manufacturing branches. (...) One important feature of larger manufacturing firms that may help account for the paradox is that they are excessively capital-intensive.” (RODRIK, 2021)

In summary, a common argument made in the literature goes as follows:

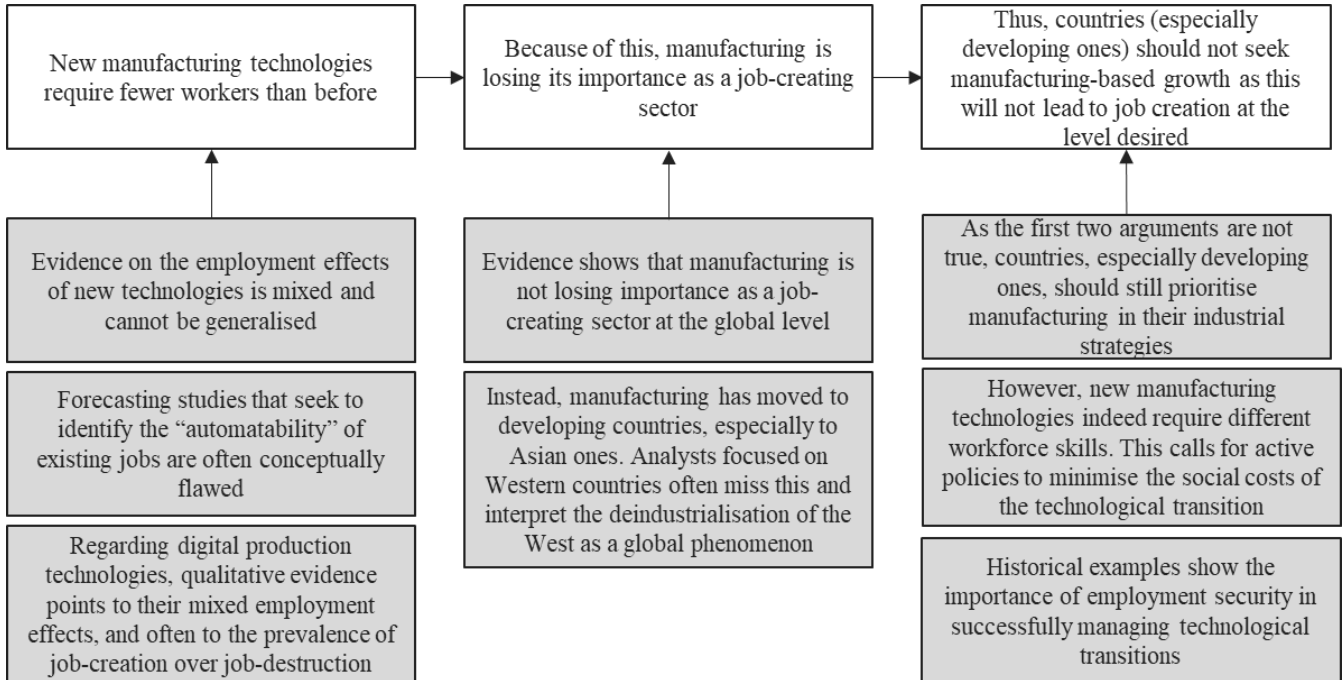
Frame 1 – Common arguments in the literature



Source: Own elaboration.

This paper questions these arguments. This will be done by presenting the following counter-arguments:

Frame 2 – Counter-arguments to the common arguments in the literature



Source: Own elaboration.

Firstly, this paper shows that the concerns about the unemployment effects of new manufacturing technologies are ill-founded. We review recent empirical works and show that the evidence about the employment effects of new manufacturing technologies is mixed. We find that new technologies have both job-creating and job-destroying effects, and the prevalence of one or the other depends on several factors, such as the type of technology, the market structure of the adopting industry, the existing industrial linkages in the country or region in question, and the prevailing labour market conditions. The effects of new technologies on employment thus cannot be generalised. We also argue that forecasting studies about the “automatability” of existing jobs are problematic as they often focus solely on the technical feasibility of new technologies and on their static job-destroying effects. In doing so, these studies give little or no attention to the economic and socio-political viability of new technologies and ignore their potential job-creating effects.

To provide evidence of this non-generalisability, we analyse the specific case of Digital Production Technologies, also known as Industry 4.0, Advanced Manufacturing, or Fourth Industrial Revolution technologies. These include technology clusters such as Artificial Intelligence and Data Analytics, the Industrial Internet of Things, 3D printing, and Smart Robotics. These technologies are commonly portrayed as potential job-destroyers and are often mentioned as a key reason why manufacturing would allegedly not be generating the same number of jobs as in the past. Through concrete examples of the applications of these technologies, as well as evidence from qualitative works, we argue that these technologies are not mainly focused on saving labour, but rather on increasing production control, speed, and efficiency, without necessarily affecting the number of workers employed.

Secondly, the paper shows that, globally, industrial jobs have not lost importance, but rather have increased slightly in recent decades. Manufacturing jobs more specifically have only slightly lost relevance, but this should be viewed with caution as there are statistical changes that make activities

traditionally categorised as manufacturing be counted as services in national accounts. In this context, we attribute the anxiety of Western authors regarding manufacturing employment to the recent shift of manufacturing activities from developed to developing countries, and from Western to Asian countries.

Based on the above counter-arguments, we defend that countries seeking economic growth and development should not be discouraged from pursuing manufacturing-based growth. However, we acknowledge that new manufacturing technologies require different workforce skills, and thus require adaptations of the skills of current and future workers. The transition period during which these new skills are developed may negatively affect some categories of workers, thus requiring adequate labour policies to minimise the social costs of the technological transition. To shed light on how countries can manage this transition period, we carry out a historical review of successful labour policies during periods of fast technological transformations and derive lessons from them. We highlight that employment security, be it at the firm or at the economy-wide level, is crucial to minimise the social costs of technological transitions and to provide a welcoming environment for new technologies.

2 Does the adoption of new manufacturing technologies lead to reduced employment?

2.1 Empirical works measuring the employment effects of adopting new manufacturing technologies

The impact of new manufacturing technologies, especially automation, on employment has been recently studied by many authors. Here, we review existing quantitative and qualitative works that tried to measure or understand these impacts.³ We analyse these works through summary tables containing five columns identifying: 1. Their definition of ‘new technologies’ or ‘automation’; 2. The database and type of data used; 3. Their methodology; 4. The unit of analysis, period, geographical region(s), and sample size; and 5. Their results. The works are divided into those focused on developed countries (Table 1) and those focused on developing countries (Table 2).

The first insight we can obtain from the empirical works in developed countries is that the results are mixed. This seems to stem partly from the different methods used and the nature of the phenomenon under study.

In terms of the methods, we can observe that the definitions of ‘new technologies’ or ‘automation’ as well as the identification strategies are varied, ranging from specific ones like “industrial robots” (generally using data from the International Federation of Robotics) to broader ones like R&D intensity, computer use, or automation patents. Scholars using different definitions of ‘new’ technologies get varying results: while broader identification strategies (that can even include product innovations) tend to show positive or mixed effects of new technologies on employment, strategies more related to process innovations (usually proxied by industrial robots) tend to have negative or neutral results.

The results also seem to depend highly on how they address the balance between ‘job-destroying’ and ‘job-creating’ effects. The job-destroying effects are the direct effects of new process technologies substituting labour (e.g. a robot taking up the role of several employees). The job-creating effects, in turn, can occur through the employment growth in the technology suppliers (e.g. the companies producing new manufacturing technologies), or through employment growth in technology adopters. The latter can occur when new technology adoption leads to market-share gains or access to new markets, increasing output and consequently employment in adopting firms. This increased output can also have secondary job-creating effects as it can lead to increased acquisitions of raw materials, machinery, intermediary products, or downstream services such as logistics and marketing, leading to potential job creation in the supply chain. Finally, it can have macro-level job-creating effects through the increased income of workers and business owners, leading to increased consumption of goods and services.

“Creative destruction” effects can also occur. These occur when new technologies destroy some occupations, but simultaneously create new ones that did not exist before (e.g., a robot may destroy a manual task, but at the same time create the roles of automation engineer and robot technicians). Some

³ This is not a systematic literature review and we do not claim for it to be exhaustive. Instead, we take a narrative approach and analyse a set of relevant existing publications and identify features that can be observed from them.

authors use market equilibrium approaches to account for the balance between these effects (ACEMOGLU; RESTREPO, 2017; CHIACCHIO; PETROPOULOS; PICHLER, 2018), some use input-output matrix analysis (GHODSI et al., 2020), some use cluster analysis (GENTILI et al., 2020), some use descriptive analysis of historical data (AUTOR, 2015), while others do firm-level analysis (DIAO et al., 2021).

The mixed results also seem to reflect the fact that the impact of new technologies on employment is country-, industry-, firm-, and technology-specific, which makes generalisations impossible. As Ugur and Mitra have pointed out, the impacts depend on a series of factors, such as the market structure of the industry, the existing backward and forward linkages of the industry, how the industry is integrated into the global economy (i.e., whether it is inserted in global value chains), and the rigidity and the power balances in the labour market (UGUR; MITRA, 2017).

Table 1 - Empirical works about the effects of new technologies on employment in developed countries

	Definition of “new technologies” or automation, and identification strategy	Database and type of data used	Methodology	Unit of analysis, period, geographical region(s), and sample size	Results
ACEMOGLU; RESTREPO (2017)	Industrial robots (per 1000 workers)	IFR: increase in robot usage across industries Censuses: share of employment by industry	Regressing the change in employment on the exposure to robots Instrumental variable (IV), fixed effects panel regression (FE)	1990-2007 US local labour markets & aggregate labour markets n=722	Negative: One more robot per thousand workers reduces the employment to population ratio by about 0.18-0.34 percentage points.
AUTOR (2015)	Computer	Census IPUMS files, American Community Survey	Quantitative descriptive statistics (change in employment)	Industry-level, US	Employment polarizations exist in the US; Growth of High-Skill Occupations has slowed down.
GREGORY; SALOMONS; ZIERAHN (2016)	Routine-replacing technological change (RRTC) Identified by increasing productivity of capital in routine tasks relative to non-routine tasks	European Union Labour Force Survey, Dictionary of Occupational Titles 1977	IV, FE	1999-2010 For Europe as a whole & at the level of 238 European regions n=12320	Positive: RRTC has on net led to positive labour demand effects across 27 European countries over 1999-2010.
DAUTH et al. (2017)	Industrial robot (per 1000 workers)	IFR Institute for Employment Research, (IAB) at the German Federal Employment Agency Integrated Employment Biographies	IV, FE	1994-2014 Local labour markets & aggregate labour markets & individuals in Germany n=402	Neutral: In Germany, there is no effect of robots on the overall level of local employment, but on its composition.
GENTILI et al. (2020)	Robot density	OECD-STAN database IFR	k-median method	2000-2015 Sectors in Denmark, France, Germany, Italy, the UK and the USA n=150 (25 sectors in 6 countries)	Mixed: Technological impacts are industry- and country-sensitive.
PIVA; VIVARELLI (2017)	R&D intensity for the covered industries, measured as the	OECD-STAN , OECD-ANBERD	Generalized Method of Moments (GMM)	1998-2011 For 11 European countries & sectors	Mixed: R&D expenditures (mainly related to product innovation) is labour-

	Definition of “new technologies” or automation, and identification strategy	Database and type of data used	Methodology	Unit of analysis, period, geographical region(s), and sample size	Results
	ratio of R&D expenditures over value added.		IV	n=3073	friendly; capital formation is negatively related to employment.
MANN; PÜTTMANN (2018)	Automation patents: a device that carries out a process independently (classified based on their text)	The United States Patent and Trademark Office (USPTO)	IV, FE	1976-2014 Sector (total, manufacture, non- manufacture) US n=4953	Positive: Automation technology has a positive effect on employment in local labour markets, which is driven by job growth in the service sector.
GHODSI et al. (2020)	Industrial multipurpose robots	2016 version of the World Input-Output Database (WIOD), IFR	FE, inclusion of lags of the explanatory variables	2000-2014 Industry All WIOD countries n=20609	Neutral: Overall impact of the installation of new robots did not statistically affect the growth of industrial employment during the period 2000–2014 significantly.
BESSEN (2019)	Computer use	Current Population Survey (CPS) US Bureau of the Census	Ordinary least squares (OLS), FE, IV, GMM	1984, 1989, 1993, 1997, 2001, and 2003 (extending to 2007 for the dependent variable). US cotton textile, steel, and automotive manufacturing industries n=1299	Mixed: Computer use is associated with declining employment in manufacturing industries, but not in other sectors.
GRAETZ; MICHAELS (2015)	Industrial robots	IFR	OLS, IV	1993-2007 17 countries n=238	Neutral: Robots had no significant effect on total hours worked, but they reduced the hours of both low-skilled and middle-skilled workers.
CHIACCHIO; PETROPOULOS; PICHLER (2018)	Industrial robot (per 1000 workers)	IFR	Regressing the change in employment on the exposure to robots IV, FE	1995-2007 Local labour markets & aggregate labour markets Finland, France, Germany, Italy, Spain and Sweden n=1129	Negative: One additional robot per thousand workers reduces the employment rate by 0.16-0.20 percentage points.
KLENERT; FERNÁNDEZ-MACÍAS; ANTÓN (2023)	Industrial robots (per 1000 workers)	IFR	Regression analysis Control variables, FE, Robustness checks	1995-2017 n = 1872 to 2567	Positive One additional robot per thousand workers increases total employment in 1.24

Source: Own elaboration.

Table 2 below describes quantitative works and case studies in developing countries. Here, works are scarcer, and the availability and reliability of data are important limitations. Methodological differences also can be observed, with some works carrying out country-level analyses (ASIAN DEVELOPMENT BANK, 2018), some doing firm-level ones (VASHISHT, 2018). Some use sophisticated causal inference tools, and some use simple OLS regressions - which may suffer from endogeneity problems.

Overall, the evidence is also mixed. Interestingly, at least three of the works reviewed compare developing and developed countries and find a higher prevalence of positive (or at least less negative) employment effects of new technologies in developing countries compared to developed ones⁴ (ASIAN

⁴ Results also differ among developed countries. For example, Germany and Japan commonly show positive effects, probably because they are large producers of robots and automation technologies.

DEVELOPMENT BANK, 2018; DUTZ; ALMEIDA; PACKARD, 2018; UNIDO, 2020). This suggests that the job-creating effects of new technologies might be larger in developing countries than in developed ones.

The results of these quantitative works are corroborated by the qualitative work carried out by Parschau and Hauge (PARSCHAU; HAUGE, 2020). They interview different stakeholders in the apparel industry in South Africa and show that, in general, stakeholders do not see any negative effects of new technologies on employment. In fact, they generally defend that new technologies would increase employment due to the expansionary effects of increased production and productivity.

Diao et al. show concerns that poor employment performance in large manufacturing firms in some African countries is related to the use of capital-intensive techniques aligned with global trends in technology. However, we should be careful in interpreting this result, since it only shows slower employment growth in manufacturing firms compared to service firms, rather than an absolute reduction in employment, and at that only for large firms (employment in small manufacturing firms were shown to have grown significantly). Moreover, this study does not consider the potential job-creating effects of these capital-intensive technologies (which could even partly explain the observed growth in the smaller firms) (DIAO et al., 2021).

Table 2 - Empirical works about the effects of new technologies on employment in developing countries

	Definition of “new technologies” or automation, and identification strategy	Database and type of data used	Methodology (data treatment, statistical tools used, etc.)	Unit of analysis, period, geographical region(s), and sample size	Results
ASIAN DEVELOPMENT BANK (2018)	Robot adoption: the percentile in the weighted distribution of changes in robot density.	IFR, ILOSTAT data on employment in developing Asia	OLS (ordinary least squares)	2005-2015 Country-level n=777	Neutral: No significant relationship between adopting robots and overall employment.
VASHISHT (2018)	Five indicators of technological change	Prowess database: technology-related variables; ASI: employment	Inclusion of lag Bias-corrected least squares dummy variables (LSDV)	1990-2012 Firms in Indian Manufacturing Sector n=1000 or so	Neutral: Technology has not reduced the aggregate employment in the Indian manufacturing sector in the long run
PARSCHAU; HAUGE (2020)	Automation technologies: equipment used for various production stages and record them during their visits.	First-hand data	Interviews with firm managers, government and union representatives Snowballing technique	2020 Firms in apparel industry in South Africa n=26	Positive: Overall impact of automation on unemployment has been negligible and is negligible. In some instances, increased automation increase employment by improving productivity at the firm level.
DIAO et al. (2021)	Capital stock as machinery, equipment and buildings	Groningen Growth and Development Centers (GGDC) 10 Sector Database	FE	1996-2017; Firm-level n=183 (for Tanzania ISIC 2 digit) n=372 (for Ethiopia ISIC 2 digit)	Mixed: Capital-intensive techniques lead to the poor employment performance of large firms that exhibit superior productivity performance.
DUTZ; ALMEIDA; PACKARD (2018)	Various	Various	Summary of several empirical works	Argentina, Chile, Brazil, Colombia and Mexico Varying periods from 1996 to 2014	Mainly positive.

Source: Own elaboration

In summary, based on the empirical studies discussed above, we find that the estimated effects of new technologies on employment depend on the definition and the identification strategies of “new

technologies” being used, and on the research methods employed, especially on how they account for the balance between job-destroying and job-creating effects. More importantly, the impacts of new technologies on employment also seem to be country-, industry-, firm-, and technology-specific, depending on a series of factors that make estimations of employment effects of new technologies a very complicated endeavour, and generalisations virtually impossible. The only potential regularity found is that the job-creating effects of new technologies appear to be larger in developing countries than in developed ones.

2.1 “Forecasting” works estimating the automatability of current jobs

In addition to the empirical works on the current impact of new technologies in employment, there are several “forecasting” studies which seek to determine the *future* impact of new technologies, especially the “automatability” of current jobs. In a famous study, Frey and Osborne (FREY; OSBORNE, 2017) predict that about 47 percent of total US employment is at high risk of computerisation. Authors who follow Frey’s and Osborne’s methodology predict huge impacts in other countries as well (BOWLES, 2014).

Many authors have criticised this methodology (ARNTZ; GREGORY; ZIERAHN, 2016; MANYIKA et al., 2017; PWC, 2017) on the grounds that new technologies substitute certain tasks within occupations, and not entire occupations, as Frey and Osbourne’s methodology assumes. These task-based approaches show that a much smaller proportion of jobs are at risk (see Table 3 below).

Table 3 - Forecasting studies about the effects of new technologies on employment

	Definition of automation and identification strategy	Database and type of data used	Methodology	Unit of analysis, geographical region(s), and sample size	Results
FREY; OSBORNE, (2017)	Computerization, Subjective assessment	O*net: features of occupations BLS: employment & wage	Task model Hand-labelling Gaussian process classifier	Occupations US	47% of US employment at high risk.
BOWLES, (2014)	Computerization, Subjective assessment	O*net: features of occupations BLS: emp & wage	Subjective assessment from FO Gaussian process classifier	Occupations EU	45% - 60% of EU employment at high risk.
ARNTZ; GREGORY; ZIERAHN, (2016)	Computerization Subjective assessment	PIAAC	Generalized linear model (GLM)	Tasks 21 OECD countries	9 % of jobs are automatable.
BORLAND; COELLI, (2017)	Computerization Subjective assessment	PIAAC Census & Labour Force Survey	GLM	Tasks Australia	9 % of jobs are automatable.
PWC, (2017)	Computerization Subjective assessment	PIAAC	Enhanced classifier algorithm based on Arntz et al.	Tasks OECD countries	30% of UK jobs could potentially be at high risk of automation.
MANYIKA et al., (2017)	Computerization Devising a list of keywords to score each task regarding its probability of being automated	O*net database World Bank	New machine learning algorithm, considering mediating factors	Tasks World	Roughly 50% of the world’s current work activities can be automated around 2055.

Source: Own elaboration

There is an even bigger problem with this literature. In general, these “forecasting” studies focus only on the technical feasibility of automation technologies and do not consider that new technologies also need to be economically viable. A well-known example of this was Adidas’ experiment of opening “speed factories” in Ansbach, Germany in 2016, and Atlanta, USA in 2017. These factories used advanced manufacturing technologies, such as 3D printing, to speed up the manufacturing process and

save labour. The plan was to make manufacturing viable even in high-wage countries and bring factories close to the final market, making it more responsive to consumer demands. The Ansbach factory employed only 160 people to produce 500,000 pairs of shoes annually and automated the entire production process, including boxing the shoes (TOWERS-CLARK, 2019). However, while technically feasible, the company soon realised that the factories were not economically viable, as it was still more economically and organisationally efficient to produce in Asia, where most of the company's manufacturing capabilities are located. In 2019, Adidas decided to close the factories and transfer the advanced machinery and technologies to their factories in Vietnam and China (COLDEWEY, 2019; CROWE, 2019).

These forecasting studies also fail to consider that there might be socio-political resistance to new technologies, such as by labour unions, traditional communities, or organised civil society groups.⁵

With the rise of Artificial Intelligence, even communities of “intelligentsias”, such as journalists, law practitioners, and economists may resist the adoption of new technologies. Furthermore, there are institutional and regulatory barriers to new technologies, especially when there are ethical issues involved (e.g. data privacy, unclear legal liability of automated systems, etc.). This limitation is acknowledged by some of the authors of the “forecasting” studies themselves (MANYIKA et al., 2017).

More importantly, however, this whole literature ignores the job-creating effects of new technologies and only discusses their job-destroying effects. Thus, the estimated share of “jobs at risk” of substitution by new technologies cannot be equated with the likely net employment losses from them.

2.3 The case of advanced digital production technologies

To make the argument clearer about the non-generalisability of employment effects, and the existence of both job-creating and job-destroying effects of new manufacturing technologies, let us now look at the example of Advanced Digital Production Technologies (ADPTs). These refer to several technology clusters, such as Artificial Intelligence and Big Data, the Industrial Internet of Things (IIoT), 3D printing, and Smart Robotics (for a definition and discussion of ADPTs, see Labrunie, 2024).

These technologies are often assumed to be an important cause of the manufacturing sector's inability to generate jobs (BALDWIN; FORSLID, 2020; HALLWARD-DRIEMEIER; NAYYAR, 2017). However, by looking closely at the concrete ways in which ADPTs are being applied to production processes, it becomes clear that *they are not only, or even mainly, about saving labour*. Based on evidence from qualitative works (ANDREONI; CHANG; LABRUNIE, 2021; IEL, 2018; LABRUNIE, 2024; LÓPEZ-GÓMEZ, et al., 2018), we can observe that labour substitution is one of the possible applications, but they also include:

- i. Improved identification of anomalies (defective products, predictive maintenance);
- ii. Better control, monitoring, and tracking of production processes and service provision;
- iii. More efficient use of energy, materials, and chemical yields;
- iv. Improved worker safety and reduced environmental impact;
- v. Better supply-chain management;
- vi. New smart/connected products;
- vii. Improved R&D and product development, and many others.

LABRUNIE (2024) investigated the use of ADPTs in the Brazilian machinery and equipment sector. Through a survey and interviews with firm managers, it was found that firm managers do not see labour substitution as the main impact of ADPTs. Managers highlight that the most important gains are in improved visualisation⁶ and control of production, which enables better management, decision-making, and even “cultural changes” in firms that adopt ADPTs. Indeed, the firm managers mentioned that, in the process of adoption of ADPTs, workers are often not substituted but simply change tasks. They also argued that the productivity gains obtained from ADPTs can lead to job creation if the increased productivity leads to firm growth. Many machinery firms that sell ADPTs, however, still highlight the

⁵ For a historical review of social resistance to technological progress, see Mokyr (1997).

⁶ By adopting ADPTs, the production processes can become much clearer and easy to visualise by firm managers, helping in the identification of inefficiencies and potential improvements.

labour-saving effects of ADPTs in their marketing strategies because it is a strong *commercial* argument. Reduction in headcount is an easy-to-understand metric and for many potential clients, it is the first indicator that they look at.

In sum, ADPTs can offer much more than simply to save labour. They are more generally cost-saving, efficiency-improving, ‘problem-solving’ technologies, and can also lead to product innovations, which can open whole new markets. Substitution of labour has a prominent space in the debate about ADPTs for the same reason that firms still use it as a commercial argument: it is an easy-to-understand concept and generates strong reactions in individuals.

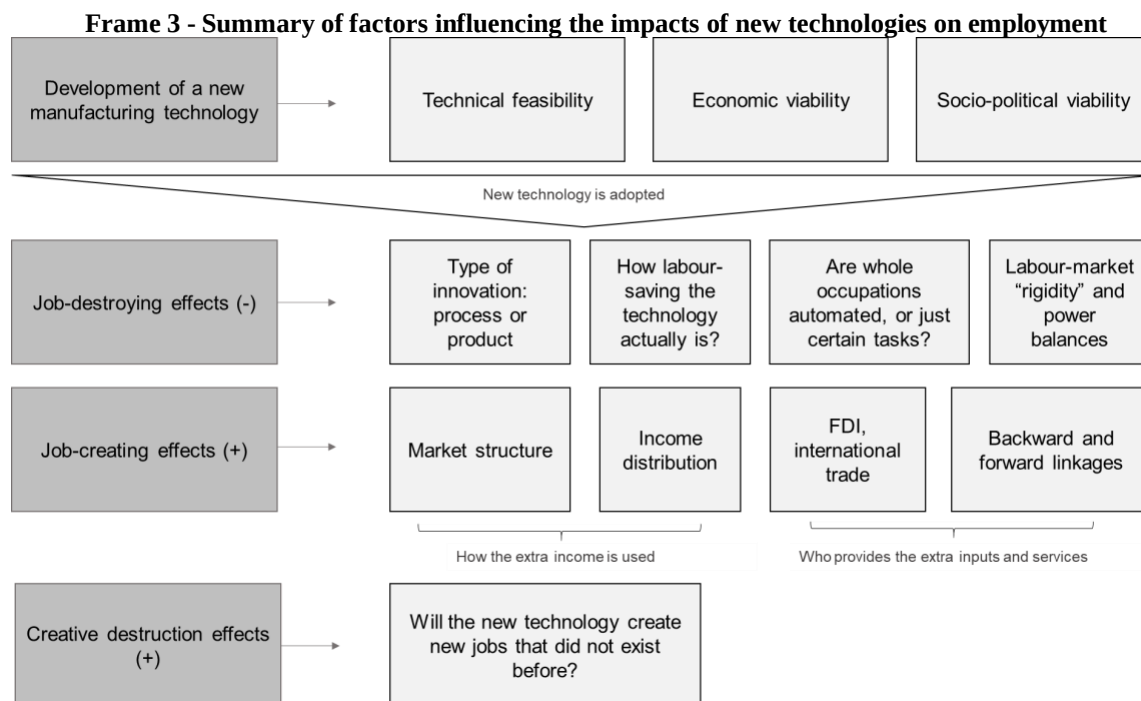
2.4 Summary of this section

The argument so far can be summarized as follows.

Just because a new manufacturing technology is technically feasible, it does not mean it will be economically viable. Even if it is economically viable, it might not be socio-politically viable. Even if it is economically and socio-politically viable, it might not be labour-saving (but rather cost-saving, time-saving, ‘problem-solving’, or even might lead to product innovations instead of process ones).

Even if a new technology is economically and socio-politically viable and labour-saving, it might substitute tasks within existing occupations, instead of substituting whole occupations. Even if the new technology does substitute whole occupations, it might still have job-creating effects that outweigh the job-destroying effects. These job-creating effects are country-, industry-, and context-specific and depend on variables such as the pattern of international trade, backward and forward linkages, income inequality, the market structure of the industry, ‘rigidities’ and power balances in the labour market, and so on.

Thus, understanding or predicting the employment effects of new technologies is a very complex issue that cannot be generalised, let alone be treated as a certainty, such as it has been in the recent discourse on the topic. The framework below summarizes some of the factors that affect the impacts of new technologies on employment.



Source: Own elaboration based on the literature review.

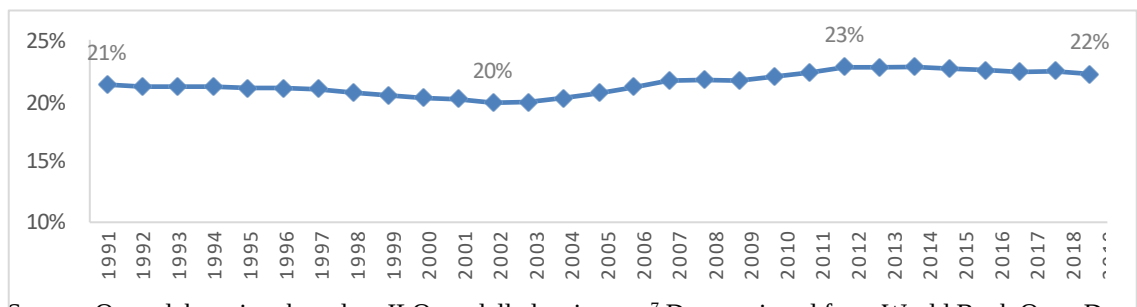
3. Is manufacturing losing importance as a job-creating sector?

As discussed above, research on the impact of technology on employment often focuses on individual country or individual sector cases. These works end up losing sight of the broader movements at the global level.

It is important to note, however, that if we take the world as a unit of analysis, the share of

industrial employment (which includes manufacturing, construction, mining and extractive industries), according to ILO data, has stayed roughly stable since 1991, and even increased in the 2000s (Figure 1).

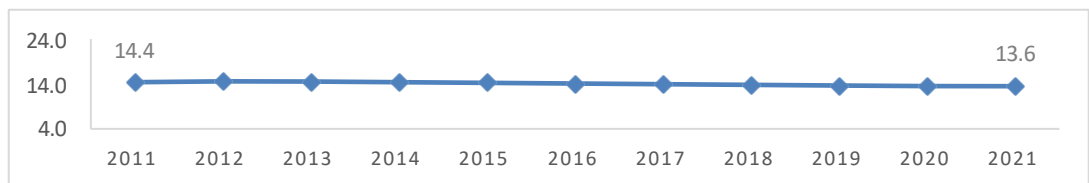
Figure 1 - World industrial employment as a share of total employment



Source: Own elaboration, based on ILO modelled estimates.⁷ Data retrieved from World Bank Open Data.

ILO global data for the manufacturing sector is not available before 2011. Since then, manufacturing’s share of total employment at the global level has reduced only slightly (by less than 1 percentage point), as shown in Figure 2.

Figure 2 - World manufacturing employment as a share of total employment



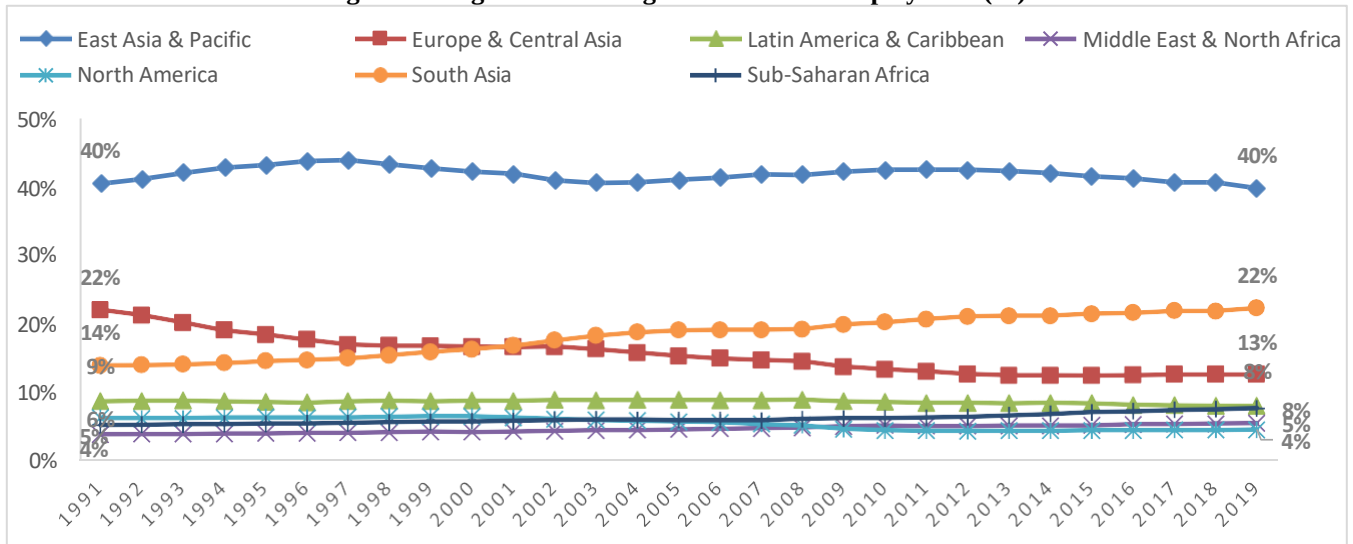
Source: Own elaboration based on data from ILOSTAT – SDG Labour Market Indicators (ILOSDG)

As pointed out by Chang (2014), this small reduction may also be a “statistical illusion”. Due to the intensification of outsourcing in recent decades, many manufacturing-related activities that before were counted as manufacturing, now are classified as services – for example, manufacturing services, which exist to support manufacturing, but are carried out by third-party service firms. This means that manufacturing activities are likely underrepresented in official statistics.

But why is there an impression by many Western observers that manufacturing has lost relevance? We propose that this is due to the geographical reorganisation of global production. This reorganisation has been characterised by a reduction of the share of developed regions (such as North America and Europe) in global industrial employment, on the one hand, and an increase in the shares of developing regions (especially that of South Asia), on the other hand. The exception is Latin America & Caribbean, which has seen a reduction in its shares, despite being a developing region (Figure 3).

⁷ This is based on ILO estimates that inputs values to countries that have missing data. More details on the methodology can be found in (ILO, 2023).

Figure 3 - Regions' share of global industrial employment (%)



Source: Own elaboration, based on ILO modelled estimates. Data retrieved from World Bank Open Data.

This global shift has also been highlighted by Haraguchi, Cheng and Smeets (HARAGUCHI; CHENG; SMEETS, 2017). Their calculations clearly show that since 1970, manufacturing value added and employment have been shifting from developed countries to developing ones. They thus conclude, similar to us, that there is no evidence supporting the decrease in the importance of manufacturing for economic development.

Given the evidence presented above, it becomes clear that both arguments presented in the recent discussion about the employment effects of new manufacturing technologies lack empirical backing. There is no evidence that new manufacturing technologies are necessarily labour-saving, and there is no evidence of a loss of importance for manufacturing as a job-creating sector at the global level. As such, countries, especially developing ones, should not be discouraged from pursuing manufacturing-based growth.

This is not to mean, however, that no adaptations are needed. Indeed, manufacturing is changing, and requiring new and different skills from the workforce. The next section analyses what this may mean for workers, and what history teaches us on how to manage labour during technological transitions.

4. How to manage labour transitions for modern manufacturing-based growth? Lessons from history

Our argument so far has shown that it is a misconception to treat new manufacturing technologies as necessarily labour-saving. However, this is not to deny that new manufacturing technologies, such as ADPTs, will have impacts on the nature of work performed in some occupations and that they will destroy employment in some industrial activities (while creating jobs in others). This creates the need for labour policies to mitigate the negative impacts on the welfare of the workers being negatively affected and, in the longer run, to reduce worker resistance to the adoption of new technologies.

Here, three historical cases are discussed to shed light on labour (or work) management during periods of fast technological transformations: the differences in labour conditions in Britain and in the US in the early 19th century; the labour management policies of post-World War II Japan; and the Scandinavian active labour market policies of the 1960s. These cases show how the impacts of technological change on employment and the nature of work can be managed in a way that minimises the negative impact on the affected workers while reducing worker resistance to technological changes.

4.1 Britain and US in the early 19th century

The US steadily caught up to the British industrial leadership in the 19th century and surpassed it sometime in the late 1880s. This phenomenon has been widely studied by many authors with different interpretations of its causes, but an undeniable fact is that it was a process of industrial development with fast technological progress across industries (especially textile, iron and steel, machinery, and

transportation). An interesting aspect of the early stages of this process in the first half of the 19th century was the very different labour conditions in the US and Britain. Some authors such as H. J. Habakkuk have pointed this out as a key factor for the US catch-up.

Before the large-scale immigration of the 1850s, manufacturing labour was scarce in the US⁸ and consequently, money wages were significantly higher than in Britain in the same period (between a third and a half higher, depending on the estimate). According to many observers of the period, this was mainly due to the opportunities offered by the open agricultural frontier in the country:

“Where land is in such plenty [wrote an observer in the 1760s] men very soon become farmers, however low they set out in life. Where this is the case, it must at once be evident that the price of labour must be very dear; nothing but a high price will induce men to labour at all, and at the same time it presently puts a conclusion to it by enabling them to take a piece of waste land.” (HABAKKUK, 1970, p. 24)

This condition is stated also in Alexander Hamilton’s 1791 *Report on Manufactures*:

“The smallness of their population compared with their territory; the constant allurements to emigration from the settled to the unsettled parts of the country; the facility with which the less independent condition of an artisan can be exchanged for the more independent condition of a farmer; these and similar causes, conspire to produce, and, for a length of time, must continue to occasion, a scarcity of hands for manufacturing occupation, and dearness of labour generally.” (HAMILTON, 1791, p. 123)

Indeed, in the 1820s, land could be purchased from the Federal Government at \$1.25 per acre, which was, according to Habakkuk, “well within the reach of a skilled labourer, who might at this time earn between \$1.25 and \$2.0 per day.” (HABAKKUK, 1970, p. 24–25)⁹. In addition, in the US most of the land was fertile and the cultivator was often also the owner.

In Britain, the labour market situation was very different. From 1815 to the 1850s, there was considerable underemployment – which was reflected in the high number of able-bodied paupers and in the declining real wages. Thus, in this period, British manufacturing had a very elastic supply of labour at the ruling wage in comparison with its US counterpart (HABAKKUK, 1967).

Becoming a farmer was also not an easy alternative in Britain as land was scarce and setting up a farm required considerable capital:

“To set up as a tenant-farmer required considerable capital, and, even if an English artisan had been able to acquire the capital, the supply of farms to be let was limited, and absorbed by the demand of the sons of existing tenants. In England, therefore, a man could, generally speaking, enter agriculture only as a labourer commanding low wages.” (HABAKKUK, 1970, p. 25)

These different labour-market conditions (among other factors¹⁰) created big differences in the receptivity of the labour force to new technologies. In England, since labour was abundant, some groups of workers were hostile to labour-saving inventions. Perhaps the most famous example of this stance was the Luddite movement by the textile artisans, which used the destruction of machines as one of their strategies¹¹ in the first decades of the 19th century. Destroying machines was also a feature of the agrarian uprisings of the 1830s against the introduction of threshing machines (MOKYR, 1992).

There are many other examples of organised resistance to new technologies in Britain, and indeed the growing power of labour movements is often seen as having contributed to the declining technological dynamism of post-Victorian Britain (MOKYR, 1997). Coleman and Macleod (COLEMAN; MACLEOD, 1986) point out that labour resistance also reinforced the “apathetic” attitude of British businessmen towards new technologies.

In the US, on the other hand, labour was much less resistant to new technologies. (HABAKKUK,

⁸ At least free-labour in the Northern US states where manufacturing development was taking place, and where slave and indentured labour was not used in large scale.

⁹ “‘The men earn here (in the cotton-textile factories at Lowell) from 10 to 20 dollars a week,’ wrote an English observer in 1842, ‘and can therefore lay by from 5 to 10 dollars, after providing for every want, so that in two or three years they accumulate enough to go off to the west and buy an estate at 1 ¼ dollars an acre or set up in some small way of business at home.’” (Habakkuk, 1970, p. 25).

¹⁰ For example, the much higher familiarity of British workers to industrial work using older technologies, and thus a much higher reluctance to change the ways of doing things.

¹¹ The Luddite movement was a complex phenomenon, only partially inspired by the fear of mechanisation – see Stevenson (2014), Thomis (1972), cited in Mokyr (1992).

1970) explains these differences:

“In England, where labour was abundant, labour-saving was likely to involve replacing, by a machine, labour that was already employed; in the U.S.A. it involved making a physically limited labour-force more effective by giving it machinery, but without displacing anyone, and with some increase in wages. There was, therefore, less opposition in America to the introduction of labour-saving practices and machines and of administrative methods for economizing labour: *the fear of unemployment was less and the likelihood greater of gaining in higher wages from the increased productivity*. In England, where there was a superabundant supply of hands and therefore ‘a proportionate difficulty in obtaining remunerative employment, the working classes have less sympathy with the progress of invention’” (p. 55, emphasis added)

And in a footnote, he adds:

“In the United States ‘the workmen hail with satisfaction all mechanical improvements, the importance and value of which, as releasing them from the drudgery of unskilled labour, they are enabled by education to understand and appreciate’” (p. 55, footnote 1)

Lazonick’s account of the differences between labour conditions in Britain and in the US in the cotton industry in the 19th century is also illuminating (LAZONICK, 1990). In his words:

“In the United States both industrial relations and the utilization of mule-spinning technology were different (...). The power that American mule spinners had to influence work conditions and pay lay in “exit” rather than “voice”. Macroeconomic conditions permitting, individual mule spinners who demonstrated their ability to do their work well could threaten to quit unsatisfactory conditions of work and pay.” (p. 118).

Lazonick also observes higher productivity and faster adoption of new technologies, such as the ring spinning frame and automatic weaving looms, in the US cotton industry, in comparison to Britain’s. In Britain, strong labour unions that had no alternative for their livelihoods were successful in keeping old technologies such as the spinning mule, in operation for much longer than in the US (LAZONICK, 1990, p. 136–137).

Although not mentioning labour resistance directly, Rosenberg documents that industrial technologies were diffusing faster in the US than in Britain. He notes that British industrial engineers that visited the US claimed that the local industry displayed an amount of ingenuity and “undaunted energy”, which Britain “would do well to imitate” (ROSENBERG, 1963, p. 420 footnote 12).

This comparison between labour conditions in the US and in Britain in the early 19th century shows that workers can be much more receptive to new technologies if they know that they will likely not get substituted by them, if they know that there is a viable alternative for their own livelihood even when they are made redundant (in the US case, becoming a farmer), and if they can actually reap some benefits from those technologies (such as higher wages and less menial work).

4.2 The Japanese labour system in post-World War II

Japan’s post-war economic growth, also known as the ‘Japanese miracle’, is another historical example of fast industrial and technological change helped by its unique employment system.

Post-war Japan’s labour conditions were underpinned by the so-called ‘Japanese Employment System’ based on three pillars: long-term (or lifetime) employment, seniority-based wages, and enterprise unionism. (DORE, 1990) highlights that these features were generally shared by most large Japanese corporations (p. 301). Itoh (1994), in turn, finds evidence that an average worker in Japan stayed longer with the same employer and changed jobs less often than an average worker in the United States (p. 235).

According to Kenney and Florida (KENNEY; FLORIDA, 1988), this system emerged from bitter post-war class struggles. Long-term employment, or tenure security, as well as remuneration schemes based on seniority and merit, were demands of the labour movement in Japan. Enterprise unionism, in turn, came out of a particular trait of Japanese working-class movement, namely, the emphasis on *production control*. The emergence of enterprise unions (confining strikes to individual firms) and the viciously competitive environment of post-war Japanese industries made work stoppages extremely

harmful to companies' profits and market shares, and thus gave workers the bargaining power to push their demands for job stability forward.

Kenney and Florida (KENNEY; FLORIDA, 1988), echoing Aoki (AOKI, 1984) and Clark (CLARK, 1979), suggest that these demands by Japanese workers did not meet strong management resistance because high labour turnover in the interwar period had been extremely costly for the Japanese industry (KENNEY; FLORIDA, 1988, p. 128). Also, Japan's condition as a latecomer meant that significant investment in training was still necessary to prepare the largely agricultural workforce for industrial mass production. It could not rely, as Britain did, on knowledge being passed on gradually and incrementally between workers, or through the apprenticeship schemes that could be traced back to the eighteenth-century artisan guilds. Keeping employees in the company was thus fundamental to ensuring a supply of skilled workers (DORE, 1987).

These agreements were central for the development of key technological and organisational innovations in Japan, the main one of which being 'lean production'.¹² According to some authors, the Japanese Employment System was beneficial for lean production because it: i) reduced incentives for workers to resist automation or work redesign; ii) facilitated skill sharing, skill upgrading, and worker interaction; iii) enabled large corporations to make sizeable investments in training, with little fear of employee turnover; iv) facilitated learning by doing; v) made management more open to information and suggestions from the shopfloor; and vi) provided the stability necessary for the functioning of the *just-in-time* system. In short, the Japanese Employment System was more adapted to the emerging knowledge-intensive economy in which innovations in products and production processes occur much more frequently (AOKI, 1988; KENNEY; FLORIDA, 1988).

We acknowledge that identifying the relationship between employment systems and innovation is a complex issue with a vast literature, whose full assessment is beyond the scope this paper. However, like in the Britain-US case reviewed, the Japanese historical experience indicates that employment security can lead to receptivity to new technologies.

4.3 The Scandinavian “social corporatism” and active labour market policies in the post-war period

The Scandinavian case is rather different from the Japanese one but ends up telling a similar story. These countries became cases of interest in the 1970s and 1980s for their ability to maintain high employment despite the global recessionary environment (ROWTHORN, 1992).

According to Rowthorn and Glyn (ROWTHORN; GLYN, 1990), the Scandinavian model of the 1960s-1980s can be characterised as 'social corporatism'. In this system:

“[T]he working class is powerful and possesses a high degree of organizational unity. This strength and unity allows the working class to develop coherent objectives and strike an advantageous bargain with other social groups. In particular, this allows full employment to be established as a major national priority. Not only is such a priority accepted by the other social groups, but labour organizations in return honour their own side of the bargain and accept the sacrifices required to achieve its employment objectives.” (p. 80)

Sweden is a particular case of interest. It was one of the fastest-growing economies in the post-war period, underpinned by a strong process of structural change and technological upgrading. It also had one of the best performances in terms of employment even in the recessionary context of the 1970s and 1980s.

Chang and Kozul-Wright point out that, like the US in the 19th century, Sweden was pressured by a shortage of cheap labour, making worker acceptance of new technologies a necessity (CHANG; KOZUL-WRIGHT, 1994):

¹² Lean production was a key factor behind Japan's catching-up success, especially in the automobile industry, revolutionising factory management around the world. The new organisation of production in Japan departed significantly from traditional US Fordism, replacing its emphasis on functional specialization, task fragmentation and assembly-line production with overlapping work roles, job rotation, team-based work units, and relatively flexible production lines (Kenney and Florida, p. 131).

“The absence of cheap labour placed additional pressure on industry to maintain export competitiveness through high product quality, technological sophistication and organisational innovation. It required that labour was willing both to accept the changes to traditional work routines implied by new technologies and to ensure that its members were suitably retrained to meet the new conditions of work” (p. 874)

They argue that in Sweden it was understood in the early 20th century that the success of creating a high-wage, high-skill economy depended on creating mechanisms for the participation of representatives of both employers and the labour movement in national economic management. The growing importance of the engineering sector in the country accustomed the labour movement to the idea that high wages, export competitiveness and low unemployment required a positive commitment towards technological change and rationalisation. The post-war Swedish model simply institutionalised this process based on fully negotiated capital-labour relations.¹³

Sweden is also known for its ‘active’ labour market policies. These policies contrast with ‘passive’ ones that are mainly based on unemployment benefits and early-retirement pensions. Active labour market policy includes measures such as: i) job brokering services; ii) training and re-training of unemployed adults to update and adapt their skills; iii) direct job creation, either as public-sector employment or subsidization of private-sector employment (CALMFORS; SKEDINGER, 1995; OECD, 1993). In Sweden and other Scandinavian countries, the guiding principle was “job security not in the firm but in the labour market” (SMUCKER; VAN DEN BERG, 1991). According to (PEKKARINEN, 1992, p. 308), in the 1980s, Sweden spent about 3 percent of GDP on “special labour market measures”, such as the ones described above.

There are not many works that directly address the issue of the impacts of the active labour market policies on workers’ behaviours towards new technologies. (SMUCKER; VAN DEN BERG, 1991) have tried to address this issue through the analysis of workers’ survey responses on employment vulnerability and degree of acceptance of technological and structural change. They compared the responses given in Sweden and in Canada, which they consider a country with a traditional ‘passive’ labour market policy.

Although their results are purely suggestive, since the surveys in the two countries are different and were made in different years, some interesting differences can be observed. In Sweden, in a national survey in 1984, 83 percent of approximately 10,000 Swedish respondents reported they had ‘not worried lately about becoming unemployed’, 13 percent reported ‘yes, now and then’ and only 3.6 percent reported ‘yes, often’. In another survey, carried out from 1980 to 1985, around 70% of the respondents thought there was ‘no risk’ or ‘hardly any risk’ to their employment over the ‘coming three years’. In Canada, a comparable survey carried out from 1980 through 1986 showed a minimum of 26 and a maximum of 38 percent of workers ‘very concerned’ about their own unemployment, or that of their household-head.

In terms of their apprehensions about technical change and industrial restructuring, in a survey in 1976 in Sweden, 45 percent of the respondents answered that they saw ‘no threat’ coming from mechanization, 37 percent saw ‘some threat’, and 13 percent saw a ‘great threat’. In Canada, in 1980, 72 percent of respondents to a similar survey thought that automation would lead to greater unemployment, and 74 percent believed that automation ‘will lead to depersonalization for the average worker’.

Again, these findings are merely suggestive, but they do indicate the validity of the argument we have been putting forward so far about the importance of employment security for the acceptance of technological change by workers. Perhaps it is no coincidence that Sweden and Japan have been consistently in the top-5 most robotised economies in the world.¹⁴

¹³ The authors go even further and argue that this organisation of the labour movement created additional pressure towards technological change *from below*, that is, through wage pressure. According to them: “Solidaristic wage bargaining by establishing industry wide wage levels, meant less efficient firms would go under or restructure whilst more efficient firms would be in a position to invest in better equipment, improving industry-wide productivity” (Chang & Kozul-Wright, 1994, p. 887, footnote 37).

¹⁴ According to data on robot density (robots per 10,000 employees) from the International Federation of Robotics. The exception is 2022, in which Sweden fell to 6th place after being overtaken by China.

4.4 A clear lesson from history

The three historical cases reviewed above show that employment security, be it internal to the firm (i.e., workers know that they will not be fired) or external to the firm (i.e., workers know that if they are fired, they will easily find another occupation, or at least will have a safety net on which to fall back on while they seek a new livelihood) are key for creating a welcoming environment for new technologies.

If this is true, countries would do well to apply this principle when dealing with the current changes to work caused by new manufacturing technologies, such as ADPTs. Countries where workers welcome ADPTs as technologies that will help them do their jobs more effectively (and even potentially increase their wages) are likely to experience a faster adoption of these technologies than in countries where mistrust in new technology prevails. For countries not lucky enough to have an abundance of job opportunities for most of their population, this means creating mechanisms for employment security, such as job stability arrangements (e.g., Japan's long-term employment policies), social security networks, and training and re-training systems (e.g., the Swedish model of active labour-market policies).

The historical cases discussed in the present article are, of course, only illustrations that we believe bring interesting insights for the current discussion on labour management in the age of digitalisation. Further works on this topic are needed to consider the different realities of countries and the specific labour effects of the emerging technological paradigm.

5 Conclusion

In this paper, we have sought to provide some counter-arguments against an emerging narrative among well-known scholars questioning the importance of manufacturing in job creation and economic development. Our paper addresses two main claims: (i) That new manufacturing technologies require fewer workers than before, and (ii) that, manufacturing is losing its importance as a job-creating sector.

Regarding the first argument, we counter-argued that the evidence available in existing studies about the employment effects of new technologies is at best mixed and at worst leans towards the positive, especially in developing countries. We pointed out that the differences in results seem to stem from the different ways in which the empirical works define 'new technologies', and the way in which they account for (or do not account for) the 'job-creating effects' of new technologies. We also argued that the employment effects of new technologies are country-, industry-, firm-, and even technology-specific, and thus cannot be generalised. Thus, employment reductions caused by new manufacturing technologies cannot be considered a certainty.

Concerning the second argument, we counter-argued by showing that, when looking at the world as a whole, there is no trend towards a reduction in industrial employment. What has occurred has been a shift in industrial employment from the developed world (North America and Europe) to the developing world, especially to Asian developing countries. This in itself may help explain the anxiety of developed country authors and their eagerness to find an explanation for this loss of industrial jobs in the West.

We also discussed the "forecasting" studies of potential job "automatability" and showed that there are definitional problems in some works (e.g., assuming that whole occupations will be automated, instead of tasks) and that the forecasting literature, in general, focuses purely on the technical feasibility, ignoring that new technologies also need to be economic and socio-politically viable. Furthermore, we have pointed out that most of these works completely ignore the 'job-creating effects' of new technologies, only focusing on 'job-destroying' ones.

Finally, we reviewed qualitative works on a specific set of new technologies, ADPTs, and highlighted that *the impact of ADPTs is not only, and not even mainly, about saving labour*. These technologies' main impact is in improving the visibility, control, lead times, and efficiency of production processes – or creating new products altogether – rather than saving labour. Labour-saving remains an important "commercial" argument due to it being an easily understood metric.

Overall, what we have tried to convey in this article is that adoption of new technologies is a complex issue, and the mechanisms through which it affects employment are even more so. Thus, the effects of new manufacturing technologies on employment should not be treated as a certainty. More importantly, developing countries should not get discouraged from investing in new technologies and

upgrading their production activities for fear of destroying jobs, or generating less jobs than they could. On the contrary, they should be worried about not being competitive, which will happen if they refuse to adopt new technologies, as that would mean getting stuck in low value-added activities and eventually being driven out of the market. Paraphrasing Isaac Asimov – the famous science fiction author: developing countries should not fear computers (or any manufacturing technology), they should fear *the lack of them*.

However, we acknowledge that manufacturing jobs are being transformed by technological changes. Many jobs will be reorganised and some jobs will disappear altogether. In the process, we agree that some livelihoods will be negatively affected. To help the discussion on what to do in these cases, we have investigated three historical cases of successful labour management practices during periods of large-scale technological transformations. The main lesson we take from them is that employment security, whether at the firm level or at the economy-wide level, seems to be essential in creating a welcoming environment for new technologies. However, more research needs to be done to contribute to our understanding of how to manage the current technological transition effectively and with minimal costs and maximum gains to workers and society.

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