

# Technical progress, organisational innovations and labour intensity

Gabriel Brondino<sup>\*,</sup>, Matteo Gaddi and Nadia Garbellini<sup>\*,</sup>

The purpose of this article is to discuss the combined effects of Industry 4.0 and lean production in the context of global supply chains on working conditions. Our thesis is that the changes of technique based on integrating Industry 4.0 technologies with lean production incur a substantial cost to labour, manifesting as increased work intensity. In Marxian terminology, they have increased the extraction rate of relative surplus value. Our contribution is closely related to the critical global value chain literature and proposes to contribute to this literature by emphasising the relevance of Industry 4.0 technologies in implementing lean production methods and reinforcing control by head companies over the entire chain. Additionally, it discusses how these dynamics manifest in companies and impact the world of work through surveys conducted with workers. These surveys were carried out in a set of Italian metal-mechanical companies involved in various global chains.

*Key words:* Global value chains, Lean production, Industry 4.0, Labour intensity, Surplus value

*JEL classifications:* B51, J88, O32

## 1. Introduction

Globalisation of production, the spread of lean production methods and the so-called ‘fourth industrial revolution’ also known as Industry 4.0, are mutually reinforcing phenomena, shaping the dynamics of global capitalism. New business models increasingly rely on just-in-time or just-in-sequence production. Companies seek to supply consumers on demand and reduce costs by eliminating inventories as much as possible. This strategy requires that the components for assembly be available when required. To do so, companies at the head of each chain must coordinate and fine-tune a complex web of suppliers, most of which are spatially dispersed. Industry 4.0 technologies facilitate this coordination. Whereas the literature on Industry 4.0

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*Address for correspondence:* Gabriel Brondino, Via Emilia Parmense, 84, 29122 Piacenza (PC), Italy; email: [gabriel.brondino@unicatt.it](mailto:gabriel.brondino@unicatt.it)

\*Università Cattolica del Sacro Cuore, Piacenza, Italy (GB); Ufficio Studi Fiom-Cgil, Roma, Italy (MG); and Università di Modena e Reggio Emilia, Modena, Italy (NG). We extend our special thanks to Fiom-Cgil, its territorial structures, and the factory delegates who made this research possible. We are also grateful to the Claudio Sabattini Foundation for their active support of this research, as well as many other projects. Additionally, we appreciate the two anonymous referees for their insightful comments and suggestions. Any remaining errors are solely the responsibility of the authors.

often focuses on automation, its truly revolutionary scope lies in interactivity and connectivity, and hence data collection and analysis. It is this property that makes relocation easier.

For most individuals in academic and policy circles, these circumstances constitute an opportunity to promote growth or development. The dominant narrative is that the state must facilitate the integration of local firms into global chains, ensure an appropriate environment for firms to innovate and prepare the workforce with the skills required by new technologies, among other policies. However, while most theoretical approaches focus on assessing firm performance, their strengths and weaknesses in the current context, little attention has been paid to analysing the impact on the labour process.

The purpose of this article is to discuss the combined effects of Industry 4.0 and lean production in the context of global supply chains on working conditions. Our thesis is that changes in technique based on the integration of Industry 4.0 technologies with lean production incur a substantial cost to labour, manifesting itself as increased intensity of work. In Marxian terminology, they have increased the extraction rate of relative surplus value.

Our contribution is closely related to Intan Suwandi's comprehensive and rigorous study (Suwandi, 2019). Suwandi's analysis is carried out from a monopoly capital perspective, as originally proposed by Baran and Sweezy (1966), and further developed by Braverman (1998 [1974]) and Bellamy Foster (2014 [1986]).

Suwandi aims to unveil the exploitative dynamics underlying the switching topology of global value chains (GVCs). The author argues that within GVCs, increases in productivity, linked to lower unit labour costs, do not result in higher wages for workers throughout the supply chain. Instead, these productivity gains lead to higher profits for the leading companies. Additionally, the author adopts Braverman's approach to assert that control over labour by the lead firm is not only direct, but also indirect, extending throughout the supply chain due to its ability to impose conditions on suppliers. Suwandi correlates these conditions with the adoption of business models such as just-in-time, the proliferation of international standards and the competitive environment among suppliers in buyer-driven markets. The author concludes by presenting case studies of two Indonesian firms engaged in GVCs, which confirm the lack of opportunities for upgrading and the complete subservience to the dictates of leading firms regarding working conditions.

This contribution expands on Suwandi's analysis by emphasising the relevance of Industry 4.0 technologies in implementing lean production methods and strengthening the control of the head companies throughout the chain. Additionally, it discusses how these dynamics manifest themselves in companies and impact the world of work through surveys conducted with workers. These surveys were carried out in a set of Italian metal-mechanical companies involved in various global chains.

The article is structured as follows. After this introductory section, the next section delves into the rise of GVCs and the GVC approach, exploring alternative critical perspectives to provide a thorough understanding of the subject matter. Section 3 offers a critique of the use of value added per worker as a measure of productivity, highlighting that it measures profitability rather than productivity. Moving forward, Section 4 critically assesses the role of Industry 4.0 and lean production methods in intensifying labour conditions within GVCs. In Section 5, the article presents a case study involving a survey conducted with Italian metalworkers. This survey examines

the effects of Industry 4.0 and lean production on various aspects, including intensification and control over work performance, required skills and integration of supply chains. Finally, the concluding [section](#) reflects on the implications of the findings and discusses future technical choices ahead in the current landscape shaped by new technological advancements.

## 2. The rise of GVCs and the new international division of labour

The landscape of global production has gone through substantial transformations since the advent of the so-called ‘second unbundling of globalization’ ([Baldwin, 2011](#)). Production/value chains, especially but not exclusively manufacturing ones, that were previously domestically integrated, began to expand or ‘lengthen’ across borders, acquiring a ‘global’ anatomy.

The notion of ‘lengthening’ encompasses two dimensions. First, a spatial dimension by which more regions/places become involved in a production process. For example, a company relocates a production phase to another country (also known as offshoring). Second, an institutional dimension by which more firms become involved. For example, a company decides not to take over a production phase and purchase the output of this phase from another company (also known as outsourcing). Both dimensions are related when a firm delegates some production phases to other firms located in a different place. Thus, offshoring and outsourcing are the concrete forms of the expansion of value chains.

As a result of this process, trade patterns began to shift, leading to increased trade in intermediate inputs (see [Timmer \*et al.\*, 2016](#)). Indeed, a growing number of scholars maintain that functional, rather than product or industry specialisation is what matters in the present context ([Timmer \*et al.\*, 2018](#); [Coveri and Zanfei, 2022](#)).

There are other distinctive features of the process that are relevant to a detailed understanding of the phenomenon. First, the expansion was led by firms located in core areas; moreover, its destination was peripheral areas. Second, the expansion followed a regional logic that mainly encompassed neighbouring countries. For this reason, some authors prefer to speak of regional value chains.<sup>1</sup> For instance, German companies mainly involved Eastern European countries in their production networks. Third, when the expansion went beyond neighbouring countries, the most relevant destination was Asia, especially China.

Several approaches were developed to understand the dynamics of the expansion of chains. Among these, the most recognised and widely diffused research program is the ‘Global Value Chain’ approach (hereinafter, GVC). The approach examines the organisational logic of various global industries and the role of firms belonging to those industries. The concepts of governance and upgrading allow the characterisation of top–down and bottom–up dynamics within a global chain, ensuring its operation ([Fernández and Brondino, 2018](#)).

The GVC approach was well received and assimilated into the conceptual framework of multilateral institutions for the formulation and prescription of development policies ([Werner \*et al.\*, 2014](#)). Such institutions promote the approach as a middle way between extreme market liberalism and state-led interventionism. The narrative unfolds as follows: the state should facilitate the integration of local firms into value

<sup>1</sup> [Baldwin \(2011\)](#), for example, talks about three major factories: America, Europe and Asia.

chains. Once integrated, the following step is to upgrade to higher value-added segments. The key to upgrading is to improve productivity through innovations, acquire new capabilities or move from a GVC in one industry to another. Attracting foreign direct investment is critical to achieve this objective.<sup>2</sup>

Despite its broad receptivity, the approach is not without criticism.<sup>3</sup> Several authors argue that it promotes a harmonious, and therefore distorted, view of the globalisation process and capitalism, downplaying hierarchical and asymmetrical power relations (see [Fernández, 2014](#)). Inherent conflicts in capitalist development, particularly the capital-labour conflict, are overlooked.<sup>4</sup> The approach focuses almost exclusively on firms and does not take into account the labour process. This can be observed, for instance, in the narrowness of the upgrade concept: the question of how the benefits from upgrading translate (or not) into better employment conditions or higher wages are completely ignored.<sup>5</sup>

Contrary to this view, an alternative approach rooted in Marxism puts forward the view that the development of GVCs has been purposefully brought about to increase the rate of exploitation of workers, taking advantage of wage differentials.<sup>6</sup>

The starting point is to frame the lengthening process as a problem of technique choice ([Mainwaring, 1974](#)). Head companies deliver a finished product by assembling domestic and imported components. The choice of the source of inputs depends on its price since the head companies seek to minimise unit costs. Whether the price of intermediate inputs is lower at home or abroad depends, in turn, on several aspects, such as transport costs, social and environmental legal protection, exchange rate risk, nominal wages and labour productivity ([Garbellini, 2021](#)).

The novelty of the current phase lies in the confluence of factors that have significantly expanded the array of alternative processes available to multinational companies (i.e. options for sourcing inputs and organising the chain).

First and foremost, it should be noted the ubiquitous trend of trade liberalisation that began in the 1980s. The multilateral agreements promoted after the creation of the World Trade Organisation stand out, particularly those of investment and intellectual property protection ([Amador and Cabral, 2014](#)). Furthermore, large developing economies such as India and China took the initiative to unilaterally reduce tariffs.

<sup>2</sup> See [Coveri and Zanfei \(2022\)](#).

<sup>3</sup> We recommend reading the first two chapters of [Suwandi \(2019\)](#) for an excellent and far more comprehensive review of the critical literature on GVC than could be covered here.

<sup>4</sup> This conflict is at best conceived as an incentive mechanism to promote innovation and improve workers' skills.

<sup>5</sup> In recent years, there has been a concerted effort to expand the concept of upgrading to encompass new dimensions, such as social and environmental upgrading. Social upgrading refers to the 'process of improvement in the rights and entitlements of workers as social actors, which enhances the quality of their employment' ([Barrientos et al., 2018](#), p. 233), whereas environmental upgrading is defined as a process aimed at 'improving or minimizing the environmental impact of GVC operations' ([Ponte, 2020](#), p. 822). However, it is important to recognise that weakened social and legal protections in developing countries may encourage outsourcing by lead firms. See [Selwyn \(2018\)](#) for an interesting discussion.

<sup>6</sup> The international division of labour has been the subject of critical economic literature for several decades. Prebisch and intellectuals associated with the United Nations' Economic Commission for Latin America formulated the core-periphery theory following the Second World War. World-Systems Analysis, a broader theoretical program aimed at analysing long-term trends in capitalism, shares numerous theoretical elements with Latin American structuralism. The emergence of dependency theory in the 1960s also held significant relevance. Furthermore, Emmanuel published the French version of *Unequal Exchange* in 1969, with the English edition following in 1972 ([Emmanuel, 1972](#)). Concurrently, scholars like Parinello and Steedman contributed to the development of the neo-Ricardian or Sraffian trade theory ([Steedman, 1979](#)).

Second, the entry of new economies into the global marketplace was also pivotal (Milberg and Winkler, 2013). The transition of former European socialist republics to market economies, the capitalist shift of China and the opening of India made available a vast and cheaper labour supply for multinational companies.

A third factor is the expansion of international capital markets that began in the late 1970s (Fröbel *et al.*, 1977). Direct investment flows deepened, often involving equipping less developed countries with cutting-edge machinery and plants. Furthermore, this equipment embodied innovative technologies that required a shorter training period and a basic set of skills.

Finally, the factor that unites all of the above is the development of new information and communication technologies (ICT) (Dicken, 2015). The development of satellites and fibre optics substantially reduced the speed and capacity constraints of information transmission, facilitating the coordination of geographically dispersed production phases.

Industry 4.0 technologies have made the coordination even easier.<sup>7</sup> Moreover, they have been functional to implement business models based on just-in-time production on a global basis. Production processes organised on just-in-time or just-in-sequence principles demand the strict respect of delivery times for suppliers, so as to have every component and input ready when needed for assembly or transformation. As will be argued, 4.0 technologies reinforce the power that head companies exert within value chains, by imposing times on direct suppliers and increasing the degree of control over work performance.

### 3. Value added per worker: a measure of upgrading or firm profitability?

As stated previously, within the GVC framework, upgrading is generally defined as the enhancement of value added per worker. This improvement can stem from various factors, such as innovation and the adoption of new technologies, the acquisition of additional capabilities and skills, the production of components with a higher quality or more complexity or a combination of these elements.

Value added per worker is one of the most used measures of productivity, with increases in value added typically corresponding to gains in productivity. However, using value added per hour worked as a metric for assessing productivity may introduce errors, as it primarily reflects profitability rather than true productivity.<sup>8</sup>

From an accounting perspective, value added is the difference between total revenues and intermediate costs. This figure includes employee compensation, gross operating surplus, mixed income and taxes less subsidies on production. Unlike net output, which is a physical concept whose deflation is feasible, value added is not tied to a specific basket of goods but instead represents a sum of different income categories. In other words, it is primarily an accounting construct.

<sup>7</sup> These technologies reinforce what Luigi Pasinetti (1973) calls *vertical integration*, that is the integration along a production chain of different, spatially dispersed production stages, by allowing to connect and manage these stages in real time. In contrast, the specialised literature on Industry 4.0 refers to this integration as ‘Horizontal’, whereas ‘Vertical Integration’ is the integration that takes place within the plant. See, for example, Oztemel and Gursev (2018).

<sup>8</sup> Classical economists and Marx had a different conception of productivity, understanding it as the total labour required to produce a single product. Pasinetti (1973, 1988) later formalised this notion into what he termed vertically (hyper-)integrated labour, encompassing the total number of hours worked, including direct, indirect and hyper-indirect labour, required to produce one unit of net output.

For illustrative purposes, let us assume that the value added,  $V$ , is the sum of wages,  $W$  and profits,  $P$ . In Marxist terminology, wages can be viewed as variable capital, while profits represent surplus value. In this case, the ratio of profits to wages may serve as the empirical counterpart to the rate of surplus value. If  $L$  represents the hours worked, value added per worker,  $V/L$ , can be expressed as:

$$\frac{V}{L} = \frac{W + P}{L} = \frac{W}{L} \left( 1 + \frac{P}{W} \right) = w(1 + e)$$

where  $w$  is the hourly wage rate and  $e$  is the rate of surplus value.

As the equation shows, the surplus value rate is a critical component of the value added per worker. Changes in the rate of surplus value result from (i) the length of the workday, (ii) the intensity of labour and (iii) the technical conditions of production (Mavroudeas and Ioannides, 2011).<sup>9</sup>

Changes in the technical conditions of production can occur either through technological innovation or by reorganising the production process with existing technologies. In practical terms, these changes often involve a reduction in the ‘porosity’ of labour, or the non-productive segments of time during the workday. Every capitalist, when planning adjustments to the technical conditions of production, takes this factor into account (see also footnote 13).

In the following section, we will explore how the adoption of Industry 4.0 technologies and lean production methods significantly increases labour intensity.

#### 4. Industry 4.0 and lean production methods

Although technological and institutional advances increase the ‘social productive forces of labor’ (Marx, 1976 [1867], p. 1024), they are generally perceived by society as an increase in the productive power of capital, that is of the means of production that aid workers. Indeed, for many, such developments lead to the integration of workers and machines, thereby limiting or attenuating the inherent labour-capital antagonism of capitalism.<sup>10</sup>

This conception is present, for example, in neo-Schumpeterian analysis and the policy prescriptions derived from it. Within this approach, the main task of the state lies in establishing the best conditions conducive to innovation within companies.<sup>11</sup> These conditions encompass various strategies, including the provision of economic incentives, both fiscal and credit-based, as well as taking over the start phases of basic research and imparting digital skills training to enhance the proficiency of the workforce (cf. Mazzucato, 2013; Cirillo et al., 2021).

However, it is not a novel view. It was also dominant within the Italian left in the late 1950s and early 1960s, and it was contested by the ‘Quaderni Rossi’ group led by Raniero Panzieri. Inspired by Marx’s analysis in the fourth section of the first book

<sup>9</sup> A fourth factor arises during the income distribution process and relates to the relationship between the value of labour power and its market price (i.e. wages).

<sup>10</sup> Coveri and Pianta (2022, p. 234), for example, sustain that ‘an expansion of the “cake” of value added can then be divided between profits and wages in a given industry, and this expansion might soften the distributive conflict’.

<sup>11</sup> The prevailing view is that innovations bring ‘the introduction of new products, greater competitiveness-based export performances, and higher profits’ (Guarascio and Pianta, 2016, p. 779).

of *Das Kapital*, the group developed the method of *workers' inquiry* to reveal the non-neutrality of science and technology in the workplace.<sup>12</sup>

Panzieri (1961), stresses that with large-scale industry, science becomes a productive power independent of labour, aimed at increasing the latter's subservience to Capital. Technology supports the division and organisation of labour as a means of exploitation. Its 'neutral' character, he argues, should be demystified: technological development involves increasing control over workers.<sup>13</sup> In the capitalist mode of production the labour process, management and organisational techniques are all incorporated into Capital and face labour as an 'extraneous "rationality"' (Panzieri, 1961, p. 61).

The infusion of new ICT in the late 1970s to early 1980s revolutionised the landscape of mechanisation and automation. Previously, machines were equipped with an unalterable mechanical memory that integrated the information defined in the design phase. No real-time reprogramming was possible, so there was no room for the so-called informal organisation. Enter the new age of ICT, and machines underwent a paradigm shift (the so-called 'flexible automation'). They could seamlessly process multiple products, change the product mix and easily introduce new models by simply reprogramming them.

Introducing these technologies allowed an increasing degree of adaptability to markets and the ability of the production system to withstand disturbing elements. Angelo Dina (1982) coined the term *technological phase*<sup>14</sup> to refer to the use of these technologies for replacing human activity in the ever-growing information generation regarding the production process. Ultimately, the technological phase served capitalists to increase the degree of flexibility in production while simultaneously reinforcing control over the work process and workers. This trend became more pronounced over time.

While the focus of investments during the 1980s was on integrating information and communication systems with the production processes beyond individual machines at the plant level, the shift to Industry 4.0 pushed forward this integration throughout the entire production chain.

As stated above, lean production aims to increase the intensity of labour by eliminating waste. All single production stages and their material and immaterial connections are carefully monitored to detect and eliminate potential sources of waste immediately, the so-called nonvalue added activities, or NVAA's for short.

The generation and exclusive control of information are crucial to this end. Industry 4.0 plants are 'smart factories' based on cyberphysical systems (CPS), online networks of machines that interact as in a social network, and the Internet of Things (IoT), virtualisation of production chains.

Software tools such as MES (Manufacturing Execution Systems), ERP (Enterprise Resource Planning), APS (Advanced Planning and Scheduling) and MRP (Material Resources Planning) are used for M2M (Machine-to-Machine) connection, with the whole system connected to a central server. These tools enable both 'vertical integration' (the connection of different departments within the same plant) and 'horizontal

<sup>12</sup> The following section discusses this methodology.

<sup>13</sup> The idea that technology is not neutral is already present in Marx (1976 [1867]). For example, he noted that limiting working hours gave an 'immense impetus to the development of productivity and the more economical use of conditions of production'. This development, Marx continues, 'imposes an increased expenditure of labor within a time which remains constant, a heightened tension of labor-power' (Marx, 1976 [1867], p. 534). It was visible to the author the tendency of Capital for 'converting every improvement in machinery into a more perfect means for soaking up labor-power' (Marx, 1976 [1867], p. 542).

<sup>14</sup> 'Fase tecnologica' in Italian.

integration' (the connection between different plants belonging to the same group or its suppliers, both located domestically and abroad).<sup>15</sup>

In addition, they allow production planning, operations scheduling, production orders to suppliers, departments, lines and workstations, real-time scheduling of production plans and the collection of the corresponding data. In other words, tools, personal devices, machines, plants and products can communicate with centralised systems continuously and in real time. A perfect match for the goals of lean production, making it possible to overcome the technical constraints that previously limited its complete application.

In terms of production planning, lean production implies the passage from a 'push' to a 'pull' logic: instead of being 'pushed' by sales forecasts, now it is being 'pulled' by customer orders, final consumers, another company or even another department within the same company, according to the positioning along the (global) value chain.

This logic allows another pillar of lean production to be implemented, that is, just-in-time: nothing must be produced upstream that is not required downstream to deliver the final product to customers, in other words, elimination of overproduction. This way, the sequence of production phases and workstations demand can be strictly synchronised in real time and continuously monitored from any connected device. In other words, Industry 4.0 combines production digitalisation with real-time data acquisition, processing and analysis through the server and cloud to optimise industrial processes (Akerman, 2018).

Industry 4.0 technologies also provide crucial support for fully implementing the logic of *kanban*, a manufacturing system in which the supply of components is regulated through an instruction card sent along the production line. Electronic *kanbans* are forwarded to each workstation, starting from general production planning via ERP and then production scheduling via MES. Fulfilled requests are recorded and their progress is shown in real time to make it possible to step in immediately when assigned times are not respected; hence, synchronisation adjustments are needed. Company information systems continuously compare actual and planned times. The latter determines the so-called *takt* time, that is, the time available to complete production given the delivery date agreed with the customer. For example, if the final product must be delivered in three days and four people work in the plant eight hours per day, the assembly has to be completed in 96 hours—which must be enough, if necessary, to intensify the pace of work and increase the individual workload.

Eliminating wastage is also achieved by providing workers with tools commonly presented as aids to lighten the workload. In reality, they are intended to reduce the time needed to perform various tasks and the chance of making mistakes. These tools include the so-called *poka-yoke* (foolproof) systems, providing detailed instructions to workstations, indicating to workers the components to be used and the sequence of operations to be carried out in order to prevent them from thinking and therefore from making errors.

Technological developments since the 1980s have been accompanied and complemented by new business models based on lean production principles. These models aim to eliminate, or at least reduce, 'wastes' and 'losses', particularly those not directly associated with productive working time.

We are accustomed to thinking that a working hour corresponds to an effective hour of working time. However, the actual work time is only a fraction of the time spent at the workplace. The relationship between the former and the latter is called 'saturation'.

<sup>15</sup> For a more extensive treatment of this topic, see Gaddi (2020A).

Breaks (recesses for personal facilities or respites dedicated to psychological and physical recovery) and waiting times (to receive new materials or instructions, or between one production phase and another) must be subtracted to obtain the actual or effective working time. These breaks and waiting times determine the ‘porosity’ of the *cycle time*.<sup>16</sup> Other activities that are involved in the cycle time include walking around the workplace to retrieve or deliver items, resetting machinery and conducting quality checks.

From the company’s point of view, these NVAAs are considered a waste of time. Lean production methods seek to eliminate or, at the very least, minimise them. Their goal is to increase the saturation of work time, thus intentionally intensifying individual workloads.

Productivity gains achieved by integrating Industry 4.0 technologies with lean production incur a substantial cost to labour, manifested as increased work intensity.<sup>17</sup> Workers’ inquiries provide useful information on how this process occurs.

## 5. Case study: workers’ inquiry

We will discuss the combined effects of Industry 4.0 and lean production in the context of global supply chains on working conditions. The results are based on a workers’ inquiry of metalworkers from northern Italy.

The workers’ inquiry approach aims at overcoming the distinction between researchers (those doing the research) and workers/union delegates (the passive object of the research); workers/union delegates are directly involved in all stages of the research: definition of objectives, planning, execution and discussion of results. Researchers are not mere external observers, but directly participate in workers’ political initiatives.

There are several stages involved in this collaborative research approach. The initial stage involves a discussion with factory delegates to define research objectives, tools and time frame. A key aspect is their drawing of a ‘rough map’ representing the workplace. This graphical representation serves as an initial guide for understanding production processes, work organisation, participation in production chains and hierarchical or co-operative worker relations, among other things. Based on these rough maps, the second phase encompasses deciding which workers to interview (trying to span all departments and different qualifications) and the topics to be addressed to the interviewees.

After these two moments of collective analysis, the interviews take place. The process follows a flexible outline, where the questions serve as prompts to encourage workers to share information based on their direct experience and professional knowledge.

Finally, the interviews are transcribed into small reports that are later collectively discussed with trade union delegates to construct a shared interpretation of the phenomena under investigation.

In the remainder of this section, we will present the conclusions drawn from interviews conducted with the Italian Federation of Metalworkers (FIOM-CGIL) in about 100 Italian metalworking plants.<sup>18</sup> The interviews focussed on the company’s technological investments, exploring workers’ awareness of these initiatives, the activities involved and their consequences on work conditions. The results are summarised in [Table 1](#).

<sup>16</sup> The cycle time is the amount of time it takes to complete any specific task from start to finish.

<sup>17</sup> In Marxian terminology, this process augments the extraction rate of relative surplus value.

<sup>18</sup> The companies belong to the following sectors: automotive, motorcycles, railway locomotives and rolling stock, electric domestic appliances, iron and steel, machinery (for agriculture and forestry,

**Table 1.** *Technological investments and consequences for working conditions*

Technological investment	Tasks concerned	Consequences for working conditions
ICT management systems (process planning, order management)	All	Subtracting labour organisation (staffing, workloads, time allocated to stages and workstations, etc.) from collective bargaining
ICT devices embedded in machinery/work tools	Machinery programming; Machinery preparation/tooling/setup activities; Auxiliary activities to those of the machinery; Machine repair/maintenance activities	Lack of knowledge of the machine's operating logic; Lack of knowledge of its mode of operation; Loss of autonomy of the worker; Increased alienation of the workers from the production process and their task; Increased work pace; Increased workloads; Monitoring of work performance
Connection between machines/lines/departments and between these and the centralised information system	Information flow management	Monitoring by company hierarchies of production processes and worker performance; Exclusion of workers from the management of data and information on production processes; Real-time reorganisation by the company of production processes and workloads
ICT systems to connect with other production units	Management of information flows, data, work and production orders, supply orders	Automation of supply orders; Loss of capacity to negotiate workloads and staffing levels; Threat of outsourcing after performance comparison with other plants/external suppliers
Electronic/ICT tools for recording production progress and tasks performed	All	Remote, real-time and continuous monitoring of work performance; Company pressure on work pace and achievement of assigned targets
Digital assignment tools	All	Loss of the ability to negotiate workloads and staffing levels; Imposition on the worker of workloads, and thus work rhythms
Human-machine interfaces	Operating machinery/equipment	Loss of autonomy in performing the task; Work activity (method and task sequences) guided by such devices; Subordination of the worker to the instructions given by the interface
Automated machines and lines	Manufacturing (assembly, welding, painting, turning, milling, bending)	Imposing work rhythms and workloads on the worker

### 5.1 Intensification and control of work performance

Interviewees suggest that the adoption of Industry 4.0 technology and lean production has accelerated the pace of work, leading to saturation. This acceleration can be attributed, in part, to the integration of working times and rhythms into machinery,

which are governed by production scripts and associated cycle times. Furthermore, companies portray these measures as objective and impervious to both formal and informal negotiations.

Computer tools serve this purpose effectively. Machines are connected to a central server and each workstation is equipped with an instruction card or a component with a barcode. When scanned with an optical reader, these barcodes allow the machine to download the corresponding script from the server, initiating the operation with the predetermined cycle time. The scripts include external parameters set by the programmers according to the management directives. In addition, script writing is increasingly outsourced, limiting worker access to important information and restricting their bargaining opportunities.

Maintenance and customer service workers suffer the same fate. They are equipped with mobile devices, where they receive through a scheduling software the list of on-site interventions to be performed, including the maximum amount of time available. In the event of unexpected difficulties, workers must speed up or limit their breaks.

The issue of control over work performance is closely related. Industry 4.0 technologies ensure pervasive and real-time control by guaranteeing the tractability of each operation and its progress. Data on the start and end of each operation are immediately uploaded to the computer system, giving visibility to those in charge of process control. In the case of manufacturing tasks, control is exercised through the association of the operator's badge with the instruction card, the machines and components used and the task performed. Additionally, in maintenance tasks, there is the aggravation of geolocalisation. For office work, various software solutions can track clicked functions, errors, overlaps, repetitions and more.<sup>19</sup>

## 5.2 Skills and man-machine relationship

According to the mainstream political narrative, one of the reasons for high unemployment in countries like Italy is the so-called 'skills shortage' or 'skills mismatch'. Outdated schooling systems are cited as a key factor, failing to provide the technical skills required by new technologies, resulting in a misalignment between supply and demand in the labour market.

Is it accurate to assert that the adoption of Industry 4.0 technologies requires a worker with higher skill levels? Contrarily, the pursuit of waste reduction involves implementing systems such as the *poka-yoke*, which, among other things, minimises the need for prolonged cognitive efforts, an NVAA to be eliminated. In this context, workers are relieved of tasks such as machine programming, operation supervision and malfunction detection. Consequently, the new technologies require workers with a more basic skill set, rather than highly specialised workers. In fact, many interviewees expressed concerns about a marked decline in their professional expertise, the importance of their role and autonomy.

earth-moving machinery, machinery for food and beverage production, metal forming machinery and machine tools, plastics and rubber machinery etc.), production and installation of telecommunications and energy equipment, general purpose machinery (fluid power, pumps, compressors, valves, gears), electronic equipment/components and semiconductors. For more details, see [Gaddi \(2018, 2019, 2020A, 2020B\)](#) and [Gaddi et al. \(2018\)](#).

<sup>19</sup> For example, managers have introduced tools such as Scrum and DevOps ([Kim et al. 2016](#)), with the explicit purpose of continuously monitoring the work progress of computer programmers.

### 5.3 Supply chain integration

As mentioned above, the advancement of ICT was instrumental in facilitating the internationalisation of production. With the emergence of Industry 4.0 technologies and the widespread adoption of lean production methods, the control of head companies over their suppliers was further strengthened. Original Equipment Manufacturers (OEMs), positioned at the forefront, enforce strict adherence to daily production schedules. Within this framework, suppliers operate under strict delivery timelines, ensuring that components arrive at the assembly line with exact precision. Moreover, this power dynamic extends beyond mere logistical coordination, affording OEMs the ability to influence working conditions and worker compensation within supplier firms.

The interviews provide interesting information on the consequences of the integration of the supply chain on labour conditions. Most of the companies in which the interviewees work are part of complex global production networks as consumers or suppliers. The close relationship with OEMs is particularly prevalent in the automotive sector, where Italian companies are strongly connected mainly to German manufacturers such as Mercedes, BMW and Porsche.

For example, Magneti Marelli, an Italian firm, produces high-tech systems and modules, primarily control units, for German OEMs. The workers mentioned Porsche as an example of a company that sets working rhythms for other firms. Customers can fully customise their cars, requiring supply chain synchronisation via Electronic Data Interchange (EDI), a centralised system that periodically delivers production plans to suppliers. Magneti Marelli receives orders to produce the specific sequence of board tools required by Porsche five days before the final assembly of the car in Germany.

This fact, in addition to confirming Suwandi's assertion about the indirect control of the lead company over the supply chain, has serious consequences for working conditions, as it implies the obligation for Magneti Marelli's labour reorganisation almost in real time (workloads, teams, shifts, etc.).

EDI and the use of shared management systems between head companies and suppliers enable the digital integration of spatially dispersed production stages. Head companies are able to transmit production orders to suppliers almost automatically while monitoring their performance and production progress in real time. This practice, also known as 'supply chain management', involves planning material flows throughout the chain. The ability to quickly switch suppliers in response to sudden interruptions or bottlenecks is called the resilience of a supply chain. Industry 4.0 technologies have the potential to push resilience to an extreme by enabling the relocation of production stages to countries with fewer labour regulations and lower wages.

Many multinational companies involved in the inquiry have resorted to outsourcing to reduce their direct industrial production. For example, ABB and Siemens utilise external companies for assembly operations. Note that relocation does not limit itself only to manufacturing, but also to 'high value added' stages such as design and software production. The ABB [White Collar Productivity](#) project is a remarkable example that aims to save one billion dollars by rationalising administration, engineering and other services. The project seeks to reverse its distribution of white-collar workers, which currently consists of 80% working in western countries such as Italy, France, Switzerland, Sweden and Germany, and the remaining 20% working in low-cost countries such as Poland, Estonia and India.

## 6. Discussion: technical choices for the future

We have discussed how the diffusion of Industry 4.0 technologies, lean production methods and internationalisation of production mutually reinforce each other. Studying these connections is of utmost importance to understand their potential impacts on working conditions, on one side, and current macroeconomic imbalances, on the other.

Although the new wave of technologies is perceived by most as purely beneficial, it is essential to stress that most of the time it contributes to increased labour intensity and a rise in exploitation levels. Furthermore, its widespread implementation also makes delocalisation to ‘low-cost’ countries easier and cheaper. Innovation efforts are aimed at developing technologies that support lean production methods, enabling head companies to monitor all geographically dispersed production stages in real time.

This existing state of affairs poses significant considerations for future technological choices. After the Second World War, European countries had to face the reconstruction effort. During the so-called economic boom, labour became scarce and increasing productivity became necessary to fully develop western industrial systems while meeting the final demand for consumption and durable goods by a population with improved living standards. Today, the situation is different, characterised by soaring unemployment rates, sluggish final demand, intensified international competition and a pressing imperative to reduce energy consumption and environmental pollution.

At this juncture, technological advances are welcomed if they reduce work fatigue and polluting emissions. Improvements aimed solely at improving company competitiveness, such as reducing production costs, may not benefit society as a whole and especially workers, as they increase labour intensity. This perspective is particularly relevant for Europe. Energy prices are driving up production costs to an unprecedented extent, and trying to remain competitive in international markets against Asia or the USA may be unrealistic. It would be preferable, instead, to boost domestic or regional demand by raising wages and reducing working times and increasing public investment in infrastructure (e.g. clean energy, transportation and telecommunication), education and health services.

It might even be convenient to turn to less productive technologies if that leads to reducing unemployment and optimising energy consumption.<sup>20</sup> In fact, sometimes the most advanced technologies are not necessarily the most labour efficient.<sup>21</sup> Indeed, they can be very labour-intensive. For instance, according to some Comau<sup>22</sup> workers, producing the latest generation of robots requires a significant amount of manual labour and craftsmanship.

There are other goals that should be taken into account for future technological choices that should take priority over profitability. Output quality, energy efficiency, environmental sustainability, improved working conditions and reduced working hours without a corresponding increase in intensity, among other objectives, are all achievable through technological advances, provided that society moves away from its fixation on productivity. Abandoning it would also contribute to dispel the myth of the coincidence between the interests of enterprises and the general public, between capital and labour.

<sup>20</sup> Note that this is unrelated to the so-called de-growth theory. Instead, it pertains to a change in the structure of final demand, which, as [Pasinetti \(1981\)](#) shows, is the crucial driving force to change the structure of production.

<sup>21</sup> Additionally, Europe’s changing demographic structure and family composition will also contribute to a partial shift in demand towards less labour-efficient technologies, particularly in caretaking activities which are largely labour-intensive.

<sup>22</sup> Comau is a leading multinational company in the automation field and part of the automaker Stellantis.

One way to steer this change is through the recovery of public sector control over the process of the choice of technique but also, and more importantly, over the change of technique.<sup>23</sup> Workers should also be included in the definition of investment plans and the monitoring of their progress, as well as in the design of new technologies, to put them at the service of improving the quality of working conditions and well-being at work. These objectives could be pursued by public companies designed not to imitate private businesses but oriented towards satisfying collective needs.

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<sup>23</sup> The distinction is from [Pasinetti \(1981, p. 189\)](#): ‘A problem of choice arises any time that a method of production has to be put into being and more than one alternative technical method is available... A change of technique is an entirely different matter. It is a process that takes place through time... It involves a movement towards a different set of possible techniques, and therefore, towards a new problem of choice’.

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