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Towards the factory 4.0? Convergence and divergence of lean models in Italian automotive plants

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Towards the factory 4.0?[1]

Convergence and divergence of lean models in Italian automotive plants

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Abstract

This paper studies the interplay in terms of techno-organisational change between the adoption of I4.0 technologies and lean production systems. Leveraging on the results of two field-work analyses conducted under a collaboration with the Sabattini Foundation and the metal workers trade union FIOM in the period 2016-2018, we compare an ensemble of factories producing both high-end/highly customised and low-end products. Emerging patterns of convergence and divergence in the techno-organisational configurations of these factories confirm that this wave of technological innovation is far from leading to total automation or the digital revolution. On the contrary, it appears to be integrated into the historical trend of "leanification" of production processes in the automotive sector, despite the organisational variety shaped by the actual implementation of this production model.

Keywords: Industry 4.0, Lean production, Automotive, Work organisation, Technological innovation, Organisational innovation.

JEL classification: L23, L6, M54, O33

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1. Introduction

A growing literature on the impact of new technologies, bundled under the heading of Industry 4.0, on the transformation of the work process in the automotive sector is emerging (among others see Krzywdzinski, 2021; Colombari *et al.*, 2020; Drahokoupil (Eds.), 2020; Krzywdzinski, 2017; Pfeiffer, 2016). This series of studies has problematised the duality between routine versus non routine working activities, questioning the deterministic prediction of a massive displacement of manual workers due to the new wave of automation and digitalisation. However, this stream has primarily looked at the technological unfolding of the production process in the automotive sector and its consequences on work and employment, without focusing on the underlying organisational models at work.

With a few notable exceptions (see, among others, Gaddi, 2020a; Butollo *et al.*, 2019), relatively less attention has been devoted to study the interplay in terms of techno-organisational change between the advent of new technologies and the lean production paradigm. Moro *et al.* (2019), Moro and Rinaldini (2020) and Cirillo *et al.* (2021) advanced along this line of research, however restricting the analysis to a subset of quite digitalised factories producing niche products, such as specialised capital equipment or luxury cars. This paper analyses and compares not only factories manufacturing high-end/highly customised products but also those devoted to the mass production of standard automotive products. By looking at the patterns of convergence and divergence in the techno-organisational configurations of these factories, the paper empirically addresses the intertwining of the so called "Industry 4.0" technologies with lean-oriented organisational models.

With this aim, we leverage on the results of two field-work analyses conducted under a collaboration with the Fondazione Sabattini and the metal workers trade union FIOM in the period 2016-2018, and we range from 3 pivotal adopters of I4.0 technologies (2 Audi-Volkswagen subsidiaries and 1 Toyota subsidiary), located in one of the most digitally advanced area in the Italian automotive sector, the Emilia Romagna region, to 5 plants belonging to the ex FCA group, now Stellantis, located across the country, both in the North and in the Centre-South, largely affected by the introduction of the World Class Manufacturing (WCM) system during the last decade (Cerruti, 2015; Dorigatti and Rinaldini, 2019).

According to our results, first, the introduction of artefacts linked to so-called 'Industry 4.0 technologies', although far from leading to total automation or the digital revolution in the automotive sector, is seamlessly embedded into the historical trend, antecedent to Industry 4.0, of organisational changes implementing the lean production system. In so doing, Industry 4.0 artefacts and the ensuing organisational changes contribute to a process of convergence towards work intensification and greater standardisation of working practices. Second, however, differently both from the ideal type of the "factory 4.0" and from an archetypical "total lean" model, we find strong forms of techno-organisational heterogeneity among all studied workplaces, mediated by factors such as plant history, market volatility, corporate culture and strategy, and product attributes. Finally, inside such a variety of configurations, an organisational dualism between plants belonging to the former FCA group and the remaining firms emerges in terms of scope and application of the lean model.

The paper is structured as follow: Section 2 presents the background theoretical framework; Section 3 highlights the research setting and methodology; Section 4 presents factory-level evidence describing the state of technological adoption and organisational practices in place together with a brief history of the factories including ownership structure, product attributes and plant functioning; Section 5 discusses the patterns of techno-organisational convergence and divergence that emerged in the empirical analysis, while our conclusions are presented in Section 6.

2. Theoretical background: lean production and Industry 4.0

The consequences of the adoption of Industry 4.0 on work processes in the automotive sector are tightly linked to the organisational model in place which since the eighties has seen a worldwide push toward lean principles (Schonberger, 1986; Womack *et al.*, 1990). Lean production uncovers both the way in which production activities are planned and executed, through stock reduction and time-to-market synchronisations, and the modes through which managerial functions are exercised to control the so called internal labour market. This latter set of activities, called High Performance Work Practices (HPWPs), include: team organisation and teamwork practices, job rotation, workers involvement in decision making and problem solving, continuous improvement activities (*kaizen*), mechanisms of feedback and communication among the workforce.

The prevalent managerial literature has interpreted the adoption of the lean paradigm as a win-win game ensuring productivity and quality gains for firms and increasing workers satisfaction. Workers, having access to easier mobility and career advancement (a more dynamic internal labour market) and participating directly with their own suggestions to better optimise the production flow, increase the overall value of the tasks executed because both better rewarded, on the one hand, and becoming more relevant in the decision-making process, on the other hand. Therefore, *ex-ante* theoretical expectations on the efficacy and adaptability of the lean model would lead to the observation of overall patterns of convergence across factories, as suggested by the global spread of the Japanese production model (MacDuffie, 1995).

Nonetheless, empirical variability in the actual implementation of the lean model has been identified, giving rise to different socio-organisational configurations embedded into plant heterogeneity. Prominent factors of variability include: corporate culture and managerial strategies, market volatility and product attributes.

- *Corporate culture and managerial strategies*: depending on the underlying corporate strategy, the total implementation of the full bundle of lean practices requires organisational changes that the management might judge at odds with its own goals (Vidal, 2017). Therefore, settling into a “lean enough” system of selected adoption might still obey to satisfying principles (Winter, 2000). Additionally, the presence or not of organised worker power and the degree of workforce disposition interact with and shape the archetypical lean model (see Vidal, 2007a; 2007b). Finally, depending on their specific corporate tradition, firms might interpret differently the way in which the lean production model is implemented in practice, as emerging when comparing the implantation in the BRICs of two automotive multinationals such as Volkswagen and Toyota (Jürgens and Krzywdzinski, 2016).

- *Market volatility:* the lean production model to properly operate requires low degree of sales variability. Whenever markets are less predictable (as in the case of Toyota transplants in Europe, Pardi, 2007, or in the case of shortages due to the pandemic induced crisis, Gaddi and Rinaldini, 2020), the conflict between system optimisation and production synchronisation may lead to deviations from the tense flow inasmuch stocks, shortages, inventories and errors start to pile up.

- *Product attributes:* end-use, price, volume, customization, durability, quality are all relevant elements in influencing the implementation of lean systems (Cirillo *et al.*, 2021). Although product attributes are relatively under-researched, scant supportive evidence highlights how the adoption of lean production models in the case of final assembly of high-end goods fosters workers' empowerment due to the greater emphasis on the product quality dimension (D'Aloisio, 2021). On the contrary, in the production of mass consumer goods, the involvement of workers following the introduction of a lean production system remains limited and total quality management becomes only a veil that hides the increase in production rhythms and the worsening of working conditions (Beaud and Pialoux, 1999).

Given the great diversity in the practical implementation of lean systems, it is not surprising that the debate on the relationship between I4.0 technologies and forms of work organisation is extremely varied (Staccioli and Virgillito, 2021). The bundles of I4.0 technologies comprises a multiplicity of technological artefacts including software of control and management of the production process interconnecting machines, so called internet of things, big data analytics and cloud computing, and finally collaborative robots. Such a set of artefacts creates the condition to automate, digitalise and interconnect the workplace, and as such it transforms the human-machine relationship and the very work process.

The most recent contributions have highlighted how the visions representing the impact of these technologies as 'disruptive' were largely overestimated and underlined the performative and rhetoric rather than the technical attributes of concepts such as 'Industry 4.0', 'digital revolution' etc., which currently represent more strategic-national-based plans (mainly for Germany, China and the U.S.) rather than actual trends of adoption (Pardi *et al.*, 2020). Especially in the automotive sector, the human-based component inside factories still remains unavoidable (Pfeiffer, 2016), while the impact of new technologies appears so far to be limited and the prospects for future deployment unclear (Pardi, 2019).

Studies based on field-work analyses are in general able to detect heterogeneous impacts of automation at the shop-floor level. In particular, the new automation processes seem to mainly concern upfront production stages, like body construction, welding and machining operations, while the assembly phase continues to be largely human-based given the specific executed tasks and the reduced scope for standardisation of functions. In the assembly phase the digitalisation of the production flow and the interconnection of machinery and equipment constitute the main innovation (Krzywdzinski, 2021; Cirillo, 2021). For this reason, although far from complete human replacement, new technologies exert significant influence on the work process (Pardi, 2019).

In terms of work organisation, despite the fact that I4.0 artefacts are generally considered to foster lean processes (Sony, 2018; Wagner *et al.*, 2017, Sanders *et al.*, 2016), the direction and extent of the impact of new technologies are not univocally understood. The characteristics of I4.0 technologies (in terms of data collection and processing capabilities, speed of information transmission, flexibility, usability, etc.) (Liao *et al.*, 2017) create the conditions for achieving unprecedented degrees of flexibility and decentralised decision-making. The majority of contributions highlight that in order to optimise the use of new technologies, it is necessary to provide for the strengthening of employee involvement and empowerment, or the reconfiguration of the organisational culture (Albano *et al.*, 2018; Kong *et al.*, 2018). Other studies, on the other hand, find precisely in the compatibility between I4.0 technologies and lean systems the confirmation that Taylorist-type forms of bureaucratic and technical control also persist. The digitalisation of production processes would be nothing more than the "extension" of the tendencies towards proceduralisation and standardisation already present in lean systems (Butollo *et al.*, 2019; Cetrulo and Nuvolari, 2019).

3. Research objectives and methodology

This study is built on the joint analysis of first-hand material from two distinct field studies: the "Emilia-Romagna I4.0" study and the "Working conditions in FCA-CNH" study. Both these studies have a trade union origin, insofar as they were conducted at the initiative of and in collaboration with the metalworkers' union FIOM-CGIL. They had however two distinct objectives: in the first case, the aim was to understand the effects of technological innovations linked to Industry 4.0 on the work organisation of some highly innovative factories (n. 8) located in the Emilia-Romagna region; in the second case, the objective was rather to question the consequences of the introduction of the World Class Manufacturing system on the working conditions in the Italian plants of the former FCA-CNH group (n. 16).

Although their purposes were different, the two projects can be considered as complementary. First of all, both studies present an analytical focus centred on the organisation of the work process at the shop-floor level and question the dynamics of techno-organisational change. In fact, both research designs assumed that innovations of a technological nature could not be analysed in isolation from those of an organisational nature. In both cases, therefore, the socio-technical perspective was central to the construction of the research designs and the analytical grids. Moreover, having set the daily work experience of shop-floor workers as the relevant level of analysis implied the use of largely overlapping interview traces. From a methodological point of view, therefore, the two studies share a similar structure, based on the collection of first-hand data, especially through the extensive use of semi-structured interviews with shop-floor workers. Finally, the collected materials are complementary, as they allow to map, in a common temporal window (2016-2018), the organisational and technological changes occurred in some of the most important Italian companies of the automotive sector.

From this global set of 24 factory case studies, in this paper we decided to analyse 8 cases (3 from the Emilia-Romagna 4.0 project and 5 from the FCA-CNH project) of factories whose main activity is related to the final assembly of automotive vehicles (cars, motorbikes, commercial vehicles or forklifts). Semi-structured interviews were administrated:

- within three automotive firms located in the outskirts of the city of Bologna (Emilia-Romagna, Italy): Toyota Material Handling Manufacturing Italy SpA (formerly known as Cesab, hereafter Cesab-Toyota) – 9 interviews, Ducati Motor Holding SpA (Ducati) – 11 interviews, and Automobili Lamborghini SpA (Lamborghini) – 11 interviews, the last two being both subsidiaries of the Audi-Volkswagen group.

- within five assembly plants belonging to the former FCA-CNH group (now Stellantis) and located all across the country: FCA Avv. Giovanni Agnelli Plant (AGAP) in Grugliasco (Piedmont) – 10 interviews, Mirafiori Assembly Plant in Turin (Piedmont) – 11 interviews, Cassino assembly Plant (Latium) – 15 interviews, Pomigliano Assembly Plant (Campania) – 9 interviews, Sevel Assembly Plant in Atessa (Abruzzi) – 17 interviews, the last being a joint venture between FCA and PSA.

The choice of cases has been guided by the aim to document the existence of a variety of lean-oriented organisational models inside however a common trend of digitalisation in the automotive sector in Italy. In addition, the choice of taking into account several plants or firms belonging to the same group (FCA plants and Audi-Volkswagen subsidiaries) had the aim of facilitating the comparison of organisational forms and managerial practices within the same ownership. Finally, our analysis extends across heterogeneous automotive product categories: luxury cars, premium automotive vehicles, mass consumer cars, commercial vehicles and material handling equipment. The analysis, of a qualitative nature, which is presented in the following pages was conducted according to a methodology inspired by that of the multiple case study (Eisenhardt, 1989; Yin, 2018). Consistently with a qualitative approach, the fieldwork materials collected in the eight cases considered in this paper was systematised and codified through a recursive process of continuous “slippage” between fieldwork materials analysis, emerging interpretations and relevant literature (Alvesson and Kärremann, 2011).

4. Factory evidence

Below, we present each of the eight cases, describing the different technological and organisational configurations of the production process as well as illustrating the characteristics of the vehicles that are assembled in these plants with background information on ownership structure and institutional configurations. As we shall see, this ensemble of factories is marked by processes of technological transformations in the period under review, but represents also examples of companies in which the actual implementation of the organisational practices inspired by the lean production paradigm has created different configurations. Besides, taking into account the heterogeneity of product categories among these plants allows us to understand to what extent the technological and organisational configuration of the production process is mediated by the market and technological proprieties of the product manufactured.

a) Cesab-Toyota Material Handling (Bologna, BO)

Products

Cesab-Toyota is a producer of forklifts together with material handling vehicles, such as light tow tractors and hand pallet trucks. In 2019, 542 workers were employed. The Toyota group acquired the factory in 2001, becoming since then Cesab-Toyota. As a result, the Toyota Production System (TPS) was gradually introduced in the site. The acquisition also entailed a change in the production process, diverted toward product diversification and customisation.

Production processes

The objective of reaching the tense production flow has resulted in the streamline of the time-to-market delivery, now set to one week, with a daily production of 75 forklifts. Processes of integration with the supply chain are at work, enabled by specific team-meetings devoted to that, and the latter interconnection represents one of the most relevant strategic priority for the management itself. Indeed, the majority of suppliers are still local (within 200 km from the plant) and leveraging on such close supply chain allows higher integration upstream and finer product customisation downstream, resulting into the reduction of the cycle-time.

In fact, takt-time has been drastically reduced: take the case of the *inspection* department dropping from 19 minutes across 3 workstations in 2007 to 6½ minutes across 5 workstations nowadays. A tense flow has however resulted into an overall intensification of working times and their flexibility, and in general of higher overtime, although the number of employees has increased of approximately 1/4 in the last six years.

Organisational practices

The most relevant organisational improvements reflect the TPS approach. Among many others, we record the substitution of local crafting "islands" with a fully fledged towed assembly line, to get a tense production flow; inventory reduction; the *kanban* system; the reorganisation of workstations requiring a re-functionality of the hierarchies, including the emergence of the Team Leader (TL) and of the "joker" (changeover operator) figures; the implementation of the so-called "5S" (Sort, Set in order, Shine, Standardise, and Sustain); the introduction of continuous improvement processes. The reconfiguration of workstations led to variable size in team domains across departments (from 10 to 25 workers). TLs are entrusted not only with technical functions, which require in-depth knowledge of the production process in the domain of competence, but also with managerial and control functions of the production activity. The interviews also testify that horizontal coordination methods (*asaichi* system), especially in the form of periodic team meetings, quickly acquired a certain legitimacy among plant operators. However, team organisation does not seem to have fostered the spread of teamwork practices: many of the collaborative dynamics seem to take place informally and outside established procedures. At the same time, according to the interviewees, the *kaizen* system – the procedures for collecting improvement proposals from workers – appears to be not yet fully consolidated.

Technological adoption

In line with the slow-approach to technology typical of Toyota, the plant manifests a relatively low degree of technological readiness. This hints at an apparent contradiction between the manufacturing of a rather advanced product, a forklift able to sense and communicate as it is endowed by sensor devices reporting errors in the post-sale phase and allowing continuous monitoring, but whose production is made out of rather obsolete tools. Among the three technological functions of I4.0, interconnection and digitalisation are quite advanced, albeit scattered across departments. However all production stages, from assembly lines to quality control and logistics are well equipped of devices enabling real-time monitoring.

Advancement in automation are still rare: indeed the manual component is at the core of the assembly process. The introduction of new digital and interconnection technologies supports the integration and the coordination between the different areas of the plant and the network of suppliers, customers and partners in which Cesab is embedded. In other words, the introduction of I4.0 artefacts in Cesab, rather than modifying the way in which production operations are carried out, seems to associate in a more direct way the individual work processes in production with the global network in which the company is embedded, in order to make the principles of Just in Time and high product customisation sustainable.

b) Lamborghini (Sant'Agata Bolognese, BO)

Products

Lamborghini is a producer of luxury sports cars and employed 1,685 units in 2019. The Audi group acquired the luxury factory in 1998. Traditionally, it operates under two parallel production lines assembling 2-seat sports car models, a standard-luxury and a superior-luxury car. The two product-tiers are differentiated with respect to internal production components and degree of customization: the engine and the aluminium shell of the lower-tier car are externally acquired while the engine block and the carbon-fibre shell of the upper-tier are made in-house, in dedicated departments. Customization, artisan assembly and handy-craft manufacturing of luxurious cars have been the core assets of the firm. The double-line approach has been kept along time, with the continuous launch of brand new models replacing those in the corresponding tier. A notable change has been the introduction of a third model in 2018, not yet started at the time of our interviews, a luxury SUV targeting larger consumer niches and expected to double overall production volumes. Indeed, the firm supply chain enjoys benefits from the parent group, the latter providing pre-assembled components.

The CFK (*Carbon Faserverstärkter Kunststoff*, German for carbon fibre reinforced polymer), a factory within the factory, being a total autonomous department producing the carbon-fibre shells, employs 200 people. The department is responsible for the transformation of raw carbon filaments into vehicle shells and other parts (such as spoilers and rear mirrors) requiring as such cutting, pressing, bonding, sandblasting, and lamination. It is endowed by department-specific R&D, industrialisation methods and timekeeping actives.

Production processes

The Audi takeover implied the passage from an artisan and "piece-by-piece" production toward a more serialised and procedurally standardised one. A progressive computerization of the production lines together with a stricter control of monitoring the cycle-time have been implemented in the recent years. The doubling of the volume of superior sports cars (from 3 to 6 vehicles per day between 2010 and 2018) brought about working times intensification, albeit takt-times are still quite relaxed particularly when compared to the automotive sector, requiring 37 minutes per workstation of vehicle assembly and 75 minutes for engine assembly.

Organisational practices

The Audi-corporate orientation led to a stricter adoption of a series of HPWP. Teams are the prevalent forms of work organisation across departments, ranging from small (4-6 workers) in quality checks and trim departments, to big (15 workers) along the assembly including a TL and a "joker". The identification of the TL, in many instances, was not done on the basis of any technical skill or competence, but rather on the basis of managerial, communication and relational skills, more suitable for a coordination role. Team meetings are held on a monthly basis and are aimed at discussing news, organisation processes and work-related issues. Workers are also encouraged to submit their improvement proposals by means of formalised participation schemes and reward practices. A highly formalised job rotation system was introduced in 2009 and has been developed and extended to all production areas over time.

Technological adoption

The factory is characterised by a widespread adoption of technological artefacts, with workstations equipped by computers and touchscreens, from the industrial engineering department to assembly lines. The degree of automation is more pronounced in the CFK department where sandblasting is performed by an industrial robot. In this area, the preparation of the machining process is regulated via touchscreens. Some collaborative robots enhance and support the human activities particularly reducing the workload related to the assembly of heavy components, like wheels. According to worker interviews, a multiplicity of manual skills have been lost while working operations have been simplified by the digitalisation and interconnection processes. However, for the very brand reputation, the hand-made component remains particularly relevant.

c) Ducati (Borgo Panigale – Bologna, BO)

Products

Ducati produces high-end motorcycles and employed 1,339 workers in 2019. First acquired by Lamborghini in 2012, then it became part of the Audi group. Ten distinct models are in parallel produced endowed by 2-3 distinct engine blocks, internally made. 4 vehicle assembly lines and 3 engine assembly lines are present with older lines of the stop-and-go type, while newer ones continuously towed. The production of motorbikes suffers from strong seasonality, given that demand peaks in late spring/summer. Therefore volume production ranges between 140 to 410 day motorbikes.

Production processes

As in the case of Lamborghini, the Audi takeover led to higher volumes and degrees of customisation coinciding with an intensification of working times and overall just-in-time orders evasion. Currently, assembly lines are modular composed by multiple 22 minutes long micro-phases. Workers can alternatively or repeat a single 22 minutes micro-phase or follow the engine/vehicle along the entire line. The modality of workers task assignment depends on contingent orders and on daily production plans entailing that a worker may be required to assemble products with a different degree of customization in a random order even within the same day. Respondents to interviews note that the increase in work rhythms is linked to the variability of production volumes, especially during periods of over-production, when the flow is reorganised according to shorter phases intensifying the repetitive nature of the work, both on assembly lines and in machine shops.

Organisational practices

The increased customisation and technological complexity of products – as a result of the introduction of electronic elements – have also made workstations more dense, reducing the possibility of operators to break away from predefined procedures. Teams range between 5 and 20 workers, according to the volume to be produced, season and department. The management of the discontinuity in production volumes has also encouraged the application of job rotation schemes which, although not extremely formalised and rather diversified between the various departments, make it possible to maintain the tension in the production flow, preventing interruptions and allowing the interchangeability of operators. The transition to the Audi-Volkswagen group also implied the introduction of worker empowerment practices, such as team meetings and suggestion gathering systems. The level of involvement of workers in these practices varies, from department to department and it is especially distinct between the production areas and the design and industrialisation areas. The frequency of team meetings varies from weekly to monthly and their nature and scope change from being capable of collectively generating solutions to complex problems to being simple devices for communicating production programmes. Moreover, contrary to what happens in non-production areas (especially R&D), where the hierarchical relationship tends to lose its significance in favour of collaboration schemes inclined to informality, in production departments the figure of the TL assumes considerable hierarchical weight, since the main function is controlling the progress of production within the domain and certifying the correct execution of tasks by operators.

Technological adoption

The plant has a distinctive dual nature inasmuch it is populated by decade-old vintages and assembly lines together with a strong digital integration and automation of the phase of mechanical machining. Automation and digitalisation are scattered. AGVs are planned to be introduced at the time of interviews, but the managerial strategy is directed towards monitoring and error reductions, by means of digital enabled technologies like the pick-to-light and the automating kitting, or the objective of the paper-less fabric.

d) FCA Avv. Giovanni Agnelli Plant – AGAP (Grugliasco, TO)

Products

The “Avv. Giovanni Agnelli Plant” (AGAP) of Grugliasco is a factory belonging to the FCA group dedicated to the assembly of luxury cars belonging to the Maserati brand. In 2009, FCA decided to take over the company that previously owned the plant, Carrozzerie Bertone, specialized in car styling, coach-building and manufacturing. Between 2009 and 2013 FCA restructured the factory with the aim of making it the production centre of luxury car models, integrating the factory's handmade philosophy, with an industrial approach aimed at improving processes. To this end, the World Class Manufacturing methodology, already applied in the other FCA plants, has been introduced at the Grugliasco plant since its reopening in 2013. In December 2015, AGAP obtained the “Bronze Medal” in the WCM. The plant currently employs around 1,700 workers and its daily production is 140 cars in two shifts. The first vehicle produced in AGAP, in January 2013, is the Maserati Quattroporte, considered the top of the Maserati range. Since July 2013, the plant has also produced the Ghibli, a 4-door luxury *coupe* that falls below the Quattroporte model in the Maserati model range. Both cars provide ample scope for customisation.

Production processes

The production cycle is divided into three departments: body shop, painting shop and assembly shop. It consists of a single production line for both models, divided into three areas (trim, chassis, final), with a maximum potential capacity of 200 cars per day over two shifts. Workers do not move along the line recording a greater saturation of workstations which compensates the reduction of physical fatigue. This occurs because of a new kitting method that provides the components to be assembled in a sequenced manner and directly on the workstations, minimizing the movement of operators, thus increasing the intensity of the performance. Within the plant, the takt-time ranged between 10 minutes (at the time of production start-up) to 5 (at the time of maximum production), to settle at 6 minutes and 15 seconds at the time the interviews were carried out.

Organisational practices

The introduction of the WCM entailed the reorganisation of production into teams of variable extension, ranging from 6 to 15 employees, depending on the department (generally larger in indirect production activities such as logistics, and smaller in assembly). At the same time, the introduction of the WCM has determined the disappearance of the “joker”, whose functions have been absorbed by the TLs, who in addition to coordinating the production process and solving problems in the domain assigned to them, also assume the function of replacing the operators temporarily absent, thus making up for the lack of staff. Despite the introduction of teams, teamwork does not seem to be particularly widespread and cooperation seems more linked to the individual intervention of workers (who, according to several interviewees, usually help each other) than to mechanisms introduced and managed by the company. Job rotation also seems to be rather marginal, since training on several workstations would generally require the support of another operator, which is difficult to sustain in a situation of shortage of staff.

Technological adoption

Almost all of the assembly operations are manual; the only exceptions are the two robots for gluing the windshield and rear window onto the car. The bodywork and painting shops are the most automated in the plant, with the presence of numerous robots and automatic welding, coating and spraying stations. On the contrary, the work in the assembly shop is highly manual, also due to the high customisation of the models. The digitalisation of the lines appears to be partial and in progress, since only some workstations are computerised and equipped with interconnected equipment. Further innovations were in the experimental stage at the time of the interviews. Finally, workers positively evaluate the changes introduced at the ergonomic level and those relating to the robotisation of some functions, which have led to a reduction in physical fatigue. At the same time, it is widely believed that ergonomic improvements have been accompanied by a significant intensification of work.

e) FCA Mirafiori Assembly Plant (Turin, TO)

Products

The Mirafiori Assemby plant was opened in 1939 and is still the flagship factory of the former FCA group. At the time of interviews, the plant had 3,850 employees and produced a small mass car (the Alfa Romeo Mito, whose production ceased in 2018) and a luxury SUV (the Maserati Levante, whose production, which began in 2016, continues today). The two cars corresponded to two separate assembly lines. The Mito line, considered at the time obsolete both for the organisation of the process and the technology in use, employed about 400 workers. The recently built Levante line, considered a new generation line (with extensive use of digital technologies and interconnection systems for machinery and equipment), employed about 1700 workers. The rest of the employees were employed in areas common to the two productions (logistics, quality control, etc.).

Production processes

As in the case of AGAP, the Mirafiori Assembly Plant is also divided into three departments: a body shop, a painting shop and an assembly shop, the production of engines having ended in 2004. The Levante line is organised in three shifts (one of which is “short”): 65 cars are produced in each of the two “standard” shifts and 40 in the “short” shift. The Mito line is organised on a single shift (in the morning) producing 80 cars. The takt-time varies between the two lines: at the time of the interviews it was set at about 5 and a half minutes on the Levante line and about 3 minutes on the Mito line. However, the production mix, dictated by the different possible engines of the two cars and by the high customisation, especially on the Levante, leads to a relative variability of the actual working times. Overall, in 2017, the Mirafiori plant produced around 50,000 vehicles. Therefore, the plant was not at full production capacity and in fact at the time there was a strong use of social safety nets, however greater in the production of the Mito than in that of the Levante.

Organisational practices

The application of the WCM is progressing and in the autumn of 2017 the plant reached the “Silver Medal”. The implementation of WCM is accompanied by a rearticulation of the hierarchy towards the bottom of the pyramid, in which the TL plays a key role. At the Mirafiori Assembly Plant, the TL seems to perform mainly managerial functions of monitoring and coordination of the production process, although it can occasionally intervene on the lines, supporting the work of the operators. The domains of TLs vary in size from one department to another, but the standard ratio is 1/7. Despite the team organisation, however, the plant is characterized by the absence of systematic team meetings and teamwork practices, nor do structured job rotation schemes appear to be present.

Technological adoption

The Mirafiori Assembly Plant appears split into two parts: one relating to the production of the Mito, on which, as it is running out, no structural investments have been made; the other relating to the production of the Levante, characterised on the contrary by the widespread and pervasive adoption of Industry 4.0 technologies, through the use of digital tools aimed both at supporting the execution of operations and at collecting data on the production flow. The trend towards digitalisation and robotisation of work processes (from the introduction of digital terminals at the workstations for carrying out some activities up to the adoption of technologically advanced machinery) appears to be relatively extensive, despite the problems that arise due to the coexistence between old and new technologies (ex. the partial adoption of new digital artefacts on older production lines). It is generally recognised that the introduction of new technologies, although it tends to reduce physical fatigue, is at the same time aimed at reducing working rhytms and reconfiguring the dynamics of control and allocation of responsibilities along the production process.

f) FCA Cassino Assembly Plant (Cassino, FR)

Products

The Cassino Assembly plant, established in 1972, employed around 4,300 employees at the time of the interviews and had a production capacity of 1,000 cars per day. After having produced cars for the Fiat, Lancia and Alfa Romeo brands, since 2014 the plant has been dedicated exclusively to the Alfa Romeo brand, for which it has been producing the Giulietta since 2010 (whose production ceased in 2020), and the Giulia and the Stelvio respectively from 2016 and 2017 (whose production is still in progress). In 2016, the plant underwent a major restructuring of the production lines, in order to adapt them to the production of the new models. In particular, the start of production of the Giulia, a car equipped with an aluminium and carbon fibre body, required the introduction of new technologies in the body shop, which now employs about 1,300 robots.

Production processes

Besides the body shop, the Cassino Assembly Plant also includes a painting shop and an assembly shop, the latter absorbing the majority of the workforce. In addition, the plant has a plastic shop that produces plastic components with which it supplies not only the assembly shop but also several FCA plants in Europe. Moreover, the plant has used social safety nets for long periods, especially in the event of production losses or during the restructuring and modernisation phases of the production lines. As a result of this, despite the fact that in 2017 the plant had experienced a production peak with over 135,000 cars produced, it was far from reaching its full production capacity. The takt-time, while varying between the various production lines, is estimated at around one minute.

Organisational practices

The Cassino plant was one of the first in which the WCM was applied, following its introduction in the two pilot plants of Melfi (Italy) and Tychy (Poland) in 2006. In 2009 the plant reached the

“Silver Medal”. The introduction of the WCM is generally associated with a significant improvement in the physical environment of the plant and the ergonomic quality of the workstations but, at the same time, its implementation also appears to be linked to the contraction of production rhythms and the further rationalisation of work operations. The introduction of the WCM is also associated with a downward re-articulation of responsibilities through an ever more extensive distribution of certification and quality control operations. Although the introduction of the TL is not recent at the Cassino plant, the figure and functions seem to have evolved in recent years. While continuing to perform a problem solving and operational support function in case of need or momentary absence of operators, the TL has become essentially a sub-managerial figure who coordinates team members, with the role of assigning tasks and duties and monitoring production progress. This new profile of TL has less technical-professional skills and seems more focused on complying with performance indicators. The size of the domains varies from department to department, but at the time of the interviews the Cassino Assembly Plant was gradually bringing the TL/domain members ratio to 1/6. Despite the introduction of teams, the plant is characterized by the absence of teamwork practices, while team meetings are rare and do not represent an opportunity to foster worker participation. Devices to support continuous improvement processes, such as the collection of suggestions, are also scarcely used, after unsatisfactory feedback was given to workers' proposals in the past. Finally, the plant also seems to lack an extensive and formalised system of job rotation and the change of workstation is instead often associated by interviewees with disciplinary logic.

Technological adoption

Assembly departments and preparation areas seem to constitute the most digitalised areas of the plant: workers interviewed testify the computerisation of production lines, the introduction of interconnected equipment, and the use of pick-to-light in kit preparation. However, the technological upgrading of assembly lines has strengthened procedural constraints for workers and allowed real-time monitoring of performance while the introduction of technical solutions that reduce physical effort has corresponded to an increase in work intensity, which in some cases is estimated by workers to be in the order of almost 20 percent (from saturation levels of 80% in the 1990s and early 2000s to almost 100% in the most recent period).

g) FCA Pomigliano Assembly Plant (Pomigliano, NA)

Products

The Pomigliano Assembly Plant, opened in 1972, was owned by the Istituto per la Ricostruzione Industriale – an Italian public holding company – before it sold the Alfa Romeo brand and related plants to the Fiat group in 1986. In 2011 the production of Alfa Romeo vehicles, assembled in the plant since its opening, was stopped and a new product was introduced, namely the Nuova Panda, previously assembled in Thychy (Poland), a mass car with very low margins and requiring significant production volumes. At the time of the interviews, the Nuova Panda was still the only model in production at the plant, which therefore had a single line.

Production processes

Production was organised in two shifts for a total production of over 400 cars per shift, which is very close to the set daily production. However, the plant remained far from the expected production capacity of 280,000 cars per year, and annual production in 2017 stood at just over 200,000 vehicles. As a result, the almost 4,500 workers of the plant have experienced various periods of temporary layoffs in recent years. The plant features a body shop, a painting shop and an assembly shop. There is also a plastic moulding department, which also serves other factories of the group, and an important warehouse, located in Nola which employs over 300 employees. The takt-time was 58 seconds at the time of the research, which made it possible to produce 62 vehicles per hour.

Organisational practices

The plant, which achieved the "Gold Medal" in relation to WCM as early as 2013, experiences today significantly high productivity levels as a result of a significant increase in the intensity of working rhythms and the saturation of workstations. In general, workers perceive that the layout improvements and technological upgrading on the lines have corresponded to an intensification of work, also linked to the change in the type of car assembled (from Alfa Romeo premium cars to the New Panda). The introduction of the WCM was also accompanied by a reorganisation of the factory hierarchy, implemented in particular through the introduction of the TL, in charge of managing a team of 5-6 operators and having the task of replacing any missing elements of the team and supporting team members in solving problems on the line. Although there are job rotation systems managed within the teams, aimed at increasing the versatility and multifunctionality of the operators, there are scarcely any teamwork practices in the plant. Finally, participation in continuous improvement processes seems to be reserved for TLs or selected workers and sometimes used for disciplinary purposes, while team meetings on the lines seem to be absent.

Technological adoption

The reorganisation of the production process according to the WCM principles started in 2009 and was accompanied by huge corporate investments which amounted, between 2011 and 2012, at about 700 million euros. The interventions concerned in particular the body and the plastic shops, which are now considered highly automated, while the assembly shop continued to rely mostly on manpower and employs nearly half of the workforce. Nonetheless, the layout of the lines has been significantly modernised, for example through the introduction of so-called "partners", i.e. tools to carry out the work in a more ergonomically adequate way, the implementation of a kitting-based supply system and the computerisation of assembly lines. However, in the opinion of the workers interviewed, the ergonomic improvement is in some cases only partial and the further rationalisation of workstations allowed by the modernisation of the lines has increased the repetitiveness of work operations while not eliminating physical effort. In addition, the process of digitalisation and interconnection of work equipment seems to have introduced new procedural constraints and increased individual control over workers' performances.

h) FCA-PSA Sevel Assembly Plant (Atessa, CH)

Products

The Sevel Assembly Plant is part of a joint-venture between FCA and PSA and deals with the production of light commercial vehicles and minivans with the Fiat, Citroën and Peugeot brands. The plant produces three models of light commercial vehicles: Fiat Ducato (which accounts for almost half of total production), Peugeot Boxer and Citroën Jumper. All three vehicles provide scope for customisation (e.g. right-hand drive or "special" vans). The plant had about 6,400 employees, including 400 temporary workers, employed almost exclusively on weekends through "weekend contracts".

Production processes

At the time of the interviews, the plant worked in three shifts, ensuring a daily production of approximately 1,200 vehicles per day. In 2017, the plant had produced over 290,000 vehicles, working almost at full production capacity.[2] Opened in 1981, the Sevel Assembly Plant consists of a body shop, two paint shops and an assembly shop. The adoption of the WCM took place in very different layout conditions from those of more recent plants, however this did not prevent the plant from reaching high levels of production efficiency, so much so that it has been awarded the WCM "Silver Medal" since 2016. The introduction of the WCM entailed first of all the modification of the lines supply systems, thanks to the introduction of the kitting method. This organisational innovation, if in some cases has improved ergonomics, it has also generally led to an intensification of workloads and to an increase in saturations, which are now close to 100%, while the takt-time has been reduced and now varies between 1 and 2 minutes.

Organisational practices

The implementation of the WCM also entailed the introduction of the TL, whose function seems however to vary according to the department: if in the body shop the TL manages a larger number of employees (15-20) and is mainly dedicated to supply management activities, in the assembly shop the TL manages a smaller number of employees and tends to be more employed in the replacement of absent workers, in the recovery of defective vehicles or in staff training. Team meetings are absent and the TLs are responsible for the formulation of improvement proposals, a task for which a portion of their working time seems to be reserved daily. Finally, the implementation of job rotation schemes seems to be hampered by the presence of several workers with reduced working capacity. For this reason, job rotation seems to vary from department to department, but overall it is scarce and weakly formalised.

Technological adoption

In the last few years, the body shop has known several investments that have led to an increase in automation of many operations (especially for what concerns automatic welding) that have resulted in a manpower reduction. In fact, this department mainly consists of semi-automatic lines where the employees' activity is very often just loading or preparation and where the introduction of robots has led to an increase in the pace of work and a reduction in break times. The second paint shop was

2 Two years later, in 2019, the exhaustion of the plant's production capacity (around 300,000 vehicles per year) prompted the company's management to extend the production of light commercial vehicles to the Gliwice plant in Poland.

built about 10 years ago, on the occasion of the production of a new version of the Ducato, and has a higher level of automation than the old Paintshop, which has nevertheless remained in operation. The assembly shop, on the other hand, is characterised by rather old lines, which at the time of the most recent investment (in the mid-2000s) did not correspond to the latest version available. According to the interviewees, the innovations introduced in this department over the last 15 years have been more incidental than structural in nature and have not significantly changed the work process. Also the introduction of partners and other equipment aimed at easing the physical burden and improving ergonomics has been limited in scope and, above all, has corresponded to a parallel intensification of working rhythms.

5. Discussion

Hereby we present a discussion of our evidence in terms of technological (5.1) and organisational findings (5.2).

5.1. Scattered technological adoption

The cross-sectional analysis shows that the automation process is scattered across departments and mainly affects body and painting shops, with a related reduction of the workforce employed. At the same time, in the assembly departments, the strategy pursued is one of low and/or collaborative automation, which only has a limited impact on labour requirements. In this respect, the robotisation processes connected to Industry 4.0 appear in continuity with the historical automation trends already experienced in the automotive sector over the last three decades (Krzywdzinski, 2021; Pil and Fujimoto, 2007).

The differences among our cases relate to the digitalisation of work processes and the use of interconnected tools on assembly lines. In some cases (Lamborghini, FCA Cassino, FCA Pomigliano), the penetration of digital technologies and instrumentation is widespread and pervasive. In others (Ducati, Cesab Toyota, FCA Mirafiori, FCA AGAP Grugliasco, Sevel Val di Sangro), the degree of digitalisation and interconnection is medium-low or partial, with clear differences between the various departments or assembly lines of the plants. These divergences could partly be explained by different company approaches to the introduction of new technologies (e.g. more cautious in the Toyota case or more enthusiastic in the plants connected to the Audi group). But they could also be linked to managerial conservative strategies avoiding to invest in the modernisation of old assembly lines producing cars proximate to be out of market (as in the case of the differences found among the plants belonging to the former FCA group).

5.2 Convergence and divergence in lean models

In all plants, the organisation of the production process is governed by the principles of lean production directed toward cost reduction, waste elimination and market synchronisation, to reach a tense production flow. Elements of convergence across factories in the application of the lean paradigm are (i) saturation of working rhythms enabled by digital tools, and (ii) process standardisation and digital control.

- *Saturation of working rhythms enabled by digital tools*: in all factories, rationalisation (waste reduction) and standardisation (control of the process) are enabled by digital technologies, which coupled with the lean systems lead to an intensification of working rhythms. The most telling example, in this case, is the restructuring of the line supplying system with the introduction of (i) kitting, facilitated by the digitalisation of warehouses and assembly lines, (ii) pick-to-light, and (iii) AGV trolleys. This technical-organisational innovation has allowed a reduction of non-value added activities and an increase in the saturation of workstations (see also Carbonell, 2020). A similar trend can be found in body and painting shops, where the introduction of new robots has led to a simplification of working operations and an increase in the pace of work.

- *Process standardisation and digital control:* the digitalisation of the production process and the interconnection of equipment and machinery do reinforce control over the work process in all factories, especially in those most affected by digital tools and software that facilitate direct and remote supervision, and allow collection of performance data with an unprecedented degree of granularity (Moro *et al.*, 2019; Moro and Rinaldini, 2020).

However, the adoption and implementation of organisational practices and managerial techniques inspired by this paradigm seem to vary in scope and extent from case to case. Elements of divergence in lean models, as discussed in Section 2, are: corporate culture and managerial strategies, market volatility and product attributes.

- *Corporate culture and managerial strategies:* the common trend of increasing saturation of working rhythms seems to be more evident in the ex-FCA plants, where the tighter working rhythms translate into increased work-related stress for operators and an overall worsening of working conditions. Variation is also found in the implementation of so-called HPWPs: if the factories belonging to the Volkswagen and Toyota groups (although with considerable differences) seem to be oriented towards forms of substantive employee empowerment (or at least tending towards this), in the factories belonging to the former FCA group the implementation of in-line and off-line worker involvement practices seems instead to remain at most nominal (see also Dorigatti and Rinaldini, 2019). This particular trend in the former FCA group may reflect the propensity to allow workers to participate in decision-making processes only in a subordinate way, i.e. when this can take place within the framework of the directives and constraints set by the company itself (Cerruti, 2015), as well as its traditional difficulty in implementing participatory practices in an organisational context characterised by cognitive schemes oriented towards conceiving business relations in a confrontational sense (and this applies to both middle managers and workers) (Volpato, 1998). But it can also be linked to precise managerial choices that respond to socio-technical constraints: an example is the difficulty in implementing structured job rotation schemes in a situation of staff shortages or high quotas of workers with reduced working capacity (Gaddi, 2020b).

- *Market volatility*: some factories seem to be confronted more than others with fluctuations in the production schedule, linked to market downturns or to the seasonality of product demand (e.g. motorbike production). In these cases, production flexibility is recovered at the cost of labour flexibility, by systematically resorting to long hours, redundancy schemes or through the use of fixed-term manpower (or, in the case of ex-FCA plants, by temporarily transferring part of the workforce from one plant to another).

- *Product attributes*: product typology seems to act as an intervening variable, although subordinate to corporate strategies. If the pressure on workers seems to be much stronger in plants producing vehicles for the mass market (like FCA Pomigliano or FCA Cassino), even among plants producing luxury cars (like between Lamborghini and AGAP Grugliasco), or highly customised light commercial vehicles (like Cesab Toyota and Sevel Val di Sangro), there seem to be strong differences with respect to work intensity and working conditions.

6. Conclusions

This paper studies the interplay in terms of techno-organisational change between the adoption of I4.0 technologies and lean production systems. Leveraging on the results of two field-work analyses conducted under a collaboration with the Sabattini Foundation and the metal workers trade union FIOM in the period 2016-2018, we compare an ensemble of factories whose main activity is related to the final assembly of automotive vehicles (cars, motorbikes, commercial vehicles or forklifts), both high-end/highly customised and low-end ones.

By looking at the patterns of convergence and divergence in the techno-organisational configurations of these factories, our results show that, differently from the standard wisdom, this wave of technological innovation is far from leading to total automation or the digital revolution. On the contrary, it appears to be integrated into the historical trend of “leanification” of production processes in the automotive sector, despite the organisational variety shaped by the actual implementation of this production model. Moreover, such divergence, found even in factories where the introduction of I4.0 technologies has been more pervasive, suggests that these technologies *per se* do not enable nor hinder forms of substantive employee empowerment. In fact, the latter does not appear to depend on the intrinsic characteristics of the new artefacts, but on the organisational context in which they are adopted.

Although the destructive impact of Industry 4.0 must certainly be relativised, the analysis of its effects on work processes would gain in depth if considered less as a new stage of technological development (as the commonly used term Fourth Industrial Revolution seems to suggest) and more as a new moment within a macro-phase of technical-organisational changes that has affected the automotive industry (and not only) over the last three decades. This shift in perspective echoes David Landes understanding of industrial revolutions along history, according to which “Machines and new techniques alone are not the Industrial Revolution” which is instead “a transformation of the organisation as well as the means of production” (Landes, 1969, p. 114).

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