Fourth industrial revolution concepts in the automotive sector: performativity, work and employment

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Abstract

In order to assess the possibility for a digital manufacturing revolution to take place in the automotive sector, the article reviews the historical evolution of automotive manufacturing technologies and organisations and analyses the impact on "fourth industrial revolution" concepts on their current transformations, taking into account in particular their consequences for employment and work. It shows that previous attempts of automating final assembly have failed because human based teamwork organizations have proved more flexible and efficient in dealing with complex assembly processes. It also highlights that the two main reasons behind these attempts in the past are not present anymore: important gaps in productivity and quality between leading and lagging firms; and shortages of skilled and unskilled manpower willing to work in automotive factories. The scope for a digital manufacturing revolution taking place in the automotive sector appears therefore limited. The analysis of the impact on automotive manufacturing of the three main "fourth industrial revolution" concepts in Germany (Industrie 4.0) in the US (advanced manufacturing), and in China (Made in China 2025) supports more than it challenges this historical understanding of the future of manufacturing in the automotive sector. It dismisses the idea that a fourth industrial revolution is under way and that a radical disruptive break will take place in the coming years.

Keywords: industry 4.0, advanced manufacturing, Made in China 2025, automation, automotive sector, work and employment

1. Introduction[1]

A substantial scientific literature has promoted the idea of an imminent digital revolution, or of a "second machine age" (Brynjolfsson and McAfee 2014). This vision has been incorporated in fourth industrial revolution concepts such as Industry 4.0 in Germany, Advanced Manufacturing in the United States, and Made in China 2025 where they have informed new sets of industrial policies. According to global consultants, the automotive industry will be at the forefront of this "fourth industrial revolution" as one of the largest capital-intensive industries, which concentrates alone around 40% of the world stock of operational robots but still employs a sizeable amount of unskilled and relatively well-paid workers (Sirkin et al. 2015).
These new technologies are presented as "disruptive", but their impact is expected to be positive for all the existing players in terms of productivity gains, better and more diversified products, better work conditions. The only problem seems to concern employment. According for instance to BCG, "fewer than 8% of tasks in the U.S. transportation-equipment industry are automated, compared with a potential of 53%" (Sirkin et al. 2015, 6). At the world level this potential would rise to 85% (2015, 15) and since robots are becoming "cheaper, smaller and more flexible" BCG forecasts that the rate of automation of all these tasks will increase exponentially worldwide to reach "near saturation in the late 2020s" (2015, 20). These alarming forecasts do not raise though great concern as they translate into straightforward scenarios and policy recommendations. Governments and firms are expected to promote these technologies in order to benefit from stronger productivity growth and should anticipate the related massive jobs losses by introducing or reforming lifelong training schemes that will also provide the fewer but more skilled workers who will interact with collaborative robots and smart technologies (Brynjolfsson and McAfee 2014). There are softer and harder versions of this view, but it is difficult to find in political arenas many controversies and debates concerning the fundamental direction of change.
As we will see below, so far the impacts of industry 4.0 technologies in the automotive industry is small, and there do not seem to be clear prospects for their future implementation and diffusion, at least in mass production. Nevertheless, according to this powerful vision, the present state of manufacturing does not matter because what we are looking at are "disruptive" transformations that only visions of the future can grasp (Rüssmann et al. 2015). Such a normative position leads to a paradox since the relationship between the present and the future is reversed. It is not anymore the future that is understood and envisioned as the product of present evolutions, but it is the present that is shaped by visions of distant futures based on the promises of digital technologies.
What we would like to propose in this article is to reverse back this perspective and reconnect empirically grounded studies of the evolution of automotive manufacturing with the future of work, employment and manufacturing. We argue that such an approach is necessary not only to produce more realistic scenarios for stakeholders and policymakers, but even more important to bring back politics and work in the debate about the future of manufacturing.

2. Are digital revolution concepts performative?

What does give to certain concepts, theory and future expectations the power of bringing into being new worlds as self-fulfilling prophecies? This question dates back at least to the work of Karl Polanyi on the "Great transformation" of modern economies under the influence of liberal economic theories (Polanyi 1944). It has acquired growing attention in recent times as the number and the importance of these phenomena have increased under the form of hypes and fashions. The question has two main dimensions: to understand by which means theories and concepts can shape the world; to identify the conditions under which this power can act. The concept of "performativity" has been developed and used in social sciences to analyse and deconstruct this type of phenomena. It has been applied to economic theories (MacKenzie et al. 2007), managerial fashions (Abrahamson and Fairchild 1999), and more recently to technology expectations (Pollock and Williams 2010). As argued by Pollock and Williams (2010), technological expectations "are crucial to the development and shaping of new science and technology" (p. 526). They "attract attention from (financial) sponsors," they "stimulate agenda-setting processes" and they "build 'protected spaces'" where new technologies can be developed (Geels and Smit 2000, 882). For these very reasons, technological expectations tend to be "hyperbolical" and "overly optimistic" (Borup et al. 2006, 286) and very few of them manage to build worlds that comply with their forecasts and visions.
In the case of industry 4.0 and digital manufacturing revolution it is too early to precisely evaluate their degree of performativity. This literature highlights however some important points that we can retain for our analysis. First, as any other technological expectations, these visions are not scientifically grounded forecasts of probable futures, but political projects that aim at shaping improbable futures. Second, while these concepts have certainly already gained strong visibility and political support, it is reasonable to assume that their visions of the future are

[1] This article is part of a research project on the future of work in the automotive sector sponsored by the International Labor Organisation. On this topic see also Pardi et al. (2019).

"overly optimistic". Indeed, most of the above literature agrees on the fact that technology expectations are becoming more unrealistic due both to the increasing complexity of the processes involved and the longer time horizon of the forecasts associated with them (Borup et al. 2006; Pollock and Williams 2010) – two features that are indeed well represented in industry 4.0 and related concepts. Third, the performativity of technology expectations is limited for objective reasons that can be identified and which explain why the new technology could not live up to the "overly optimistic" expectations.

In the current debate about the automation of work, some of the assumptions on which the new "digital revolution" doxa has been built have already started to be challenged and contested (Paus 2018). D. Autor (2015) has in particular developed two convincing arguments that dismiss the current "automation anxiety". The first argument is historical and consists in looking back at previous phases of "automation anxiety". Autor argues that previous phases of "automation anxiety" proved systematically wrong, and he suggests that this could be also the case in the current configuration. The second argument is analytical and consists in understanding the reasons why these "doom" prophecies turn out to be wrong in the past and see if they still apply today.

In the next section we will start by looking back at the previous attempts to fully automated automotive assembly in the 1980s and 1990s and explain why they have failed. We will then look at the present attempts to revive high technology automation in the automotive sector in Germany, the US and China at the light of three political projects: the German "Industrie 4.0 platform", the US "advance manufacturing platform" and "Made In China 2025".

3. Workplace automation in the automotive sector: historical patterns and current prospects

Since the introduction of mass production in the 1910s the stamping, welding and painting of the car have been progressively mechanized paving the way in the 1970s and 1980s to the automation of most of these assembly operations. By contrast final assembly where most of the variety and complexity of the assembly process converged was still manually intensive and concentrated over 60% of the total employment in the factories (MacDuffie and Pil 1997, 247). The most important efforts in terms of automation focused in the 1980s on breaking the final assembly bottleneck to move towards the engineers' dream of an almost unmanned factory. These efforts came in particular from carmakers that suffered in the 1970s from productivity and quality problems and saw the automation of the whole assembly process as the ultimate solution to these issues. GM and Fiat were amongst the most engaged in this process (Camuffo and Volpato 1997). These were also companies that had poor industrial relations and struggled to keep control of the shop floor. In the case of Volkswagen, another company that pushed for the automation of final assembly, this was driven mainly by the engineering search for efficiency through technological "great leaps forward" (Jürgens et al. 1997, 397). But in both cases the result of these massive efforts were extremely expensive factories with high level of final assembly automation like the Fiat Cassino plant, the GM Hamtramck plant and the VW's Hall 54 in Wolfsburg, whose performances were disappointing due to frequent machine stops, which affected productivity and quality, and low flexibility which constrained the introduction of new models (Fujimoto 1997, 216–17). By contrast, the Japanese factories that were leading the international comparison in terms of work productivity and quality performance presented a much lower level of automation, in particular in final assembly.

According to Fujimoto, Japanese companies were pursuing a "low-cost automation" strategy: where the "high technology" strategy focused on "automation for the sake of automation regardless of its overall competitive performance", the "low-cost automation" strategy focused on overall competitiveness "…with the simplest, most reliable, and least expensive automation equipment" (Fujimoto 1997, 217). Because of the key role of team-working in balancing the production lines, adjusting production volumes to demand, and improving production processes, the optimal automation ratio of final assembly was here estimated "to be near zero" (Fujimoto 1997, 219).

During the second half of the 1980s, following the successful "transplantation" of Japanese carmakers in the US, Western carmakers abandoned the "high technology" strategy and started to reorganize their factories according to the "lean production" paradigm. Paradoxically, this was also the time when the "low cost automation" strategy associated with lean production entered into crisis in Japan. What this strategy produces is a very efficient but also fragile assembly line where work is hard and stressful, and in the context of the economic boom of the 1980s young Japanese did not want anymore to work in these factories. This situation led to a second wave of automation efforts pushed this time by Japanese carmakers and oriented towards improving the attractiveness of assembly operations by automating the most unattractive work stations (Fujimoto 1997, 219–26). As in the case of the Western experiments with higher level of final assembly automation, the results have not been very successful due to their high capital cost and limited flexibility and once the post-bubble recession started they were all abandoned. The solution to the work crisis consisted eventually in reducing the pressure of the lean organization by segmenting the lines, introducing buffers and use fixed stations for sub-assembly. This "human motivating" approach was notably introduced at the Kyushu factory of Toyota in the early 1990s and became later the norm for all the Toyota factories (Shimizu 2000).

The second part of the 1990s saw the abandon by all the carmakers of the “high technology” strategy and a general convergence towards the “low cost” and “human motivating” automation strategies associated with lean production. As a result, at the end of the decade the rate of automation in assembly had not progressed significantly by comparison with the late 1980s, even though more flexible robots had been introduced in the body and paint shops (MacDuffie and Pil 1997). At this time, forecasts anticipated for the next decades a growing diffusion of automation, including in final assembly, as the technologies available would become cheaper, more flexible and integrated with computer based communication systems (Hsieh et al. 1997, 36). The year 2000s and 2010s have not confirmed these forecasts as the stocks of assembly robots in the automotive sector have tended to stagnate and the average rate of automation in global automotive factories has not increased or has even decreased in some cases. Two main connected factors account for this evolution.

A first factor is the supply of labor. Following the collapse of Soviet Union, the entry of China in the WTO and the creation and extension of free trade zones in all the major economic regions, hundreds of millions of workers have been added to the world supply of workforce. As a result, the availability, cost and willingness to work of unskilled and skilled workers have ceased to be a problem for the automotive industry, at least for the time being. Rather than trying to pursue automation, carmakers have structured regional value chains and shifted production to low-wages countries in order to reduce their costs.

A second factor is related to one of the precondition identified by Jürgens et al. (1997) for the further diffusion of automation: the reduction of product variations in order to improve the design for automation. The 2000s and 2010s have rather seen a constant increase in product variations pushed by direct competition in all the main markets and the rapid introduction of new products (Jullien and Pardi 2013). If the development of modular platforms has allowed to increase the number of common parts between product variations, the variety and complexity of the assembly process, and in particular of final assembly has constantly increased reinforcing the role of skilled experienced line-workers in the organization and optimization of the production flow (Jürgens and Krzywdzinski 2016; Pardi 2017). Under these conditions low-cost automation strategies should prevail.

While factory 4.0 and other related concepts are now pushing for a revival of high-technology automation strategies, the two main drivers that have spurred previous automation waves in the automotive sector appear to be absent: neither the productivity and quality problems that affected Western carmakers in the 1980s, nor the labor shortage and workers’ discontent that affected Japanese carmakers in the early 1990s are present today[2]. What is again present and diffused by the Industry 4.0 vision is the drive for automation for the sake of automation. As in the 1980s, “Technology- oriented notions, such as *the higher the automation ratio, the better, the more intelligent the robots, the better* or *the closer to unmanned operations, the better,* tend to be taken for granted, regardless of their competitive consequences” (Fujimoto 1997, 215). The question is whether this ideological oriented drive will be enough to spur a new wave of automation in the automotive sector – the disruption revolutionary hypothesis –, and if it is not, what other consequences it might have on the organization of production and work from a path-dependent perspective.

4. Industrial revolution concepts as political projects

The years 2000s have been marked by declining contribution of manufacturing to GDP, historically low levels of investment in industrial equipment, and deterioration in the trade balance of manufacturing goods in almost all mature economies. These underlying negative trends have been exacerbated by the impact of the 2008-2009 crisis, triggering the reactivation of industrial policies at national and supranational level. This is the context that sees the emergence of the industry 4.0 and advanced manufacturing platforms and projects in Germany and the US, followed by Made in China 2025.

The “Plattform Industrie 4.0” was founded by the three industry associations VDMA (mechanical engineering), Bitkom (IT) and ZVEI (electrical engineering) in 2013 before being placed under the political leadership of the German government in 2014. From a policy perspective, Industry 4.0 is a campaign to mobilize significant public funding and private investment for technological modernization and innovation (Pfeiffer 2017). An important motivation here is the perception that Germany is strong in manufacturing, but in the field of information technologies threatens to fall behind the US, but also countries like China. The core idea of Industry 4.0 is to develop a global competitive advantage from the combination of manufacturing expertise and IT (Kagermann et al. 2013). The American Manufacturing Initiative was launched by president Obama in 2011 and led in 2012 to the creation of the Advanced Manufacturing Partnership (AMP). The focus here is on the “advanced manufacturing sectors” which are perceived as “essential to national security” (PCAST 2011, 14), and in particular on the aerospace sector (Daudt and Willcox 2016). Finally, Made in China 2025 (MiC 2025) has been promoted since 2013 as a part of China’s strategy of “innovation-driven development”. It gives a strong role to China’s new rising multinationals in mid- and high-technologies such as solar systems, wind turbines,

[2] There are fears of labor shortage in Germany, but there is no much comparison with the structural crises of the 1980s or the recruitment problems in Japan of the 1990s.

LED, household appliances or, most prominently, in telecommunications and advanced internet services (Butollo and Lüthje 2017)[3].

Despite their important differences, the Industrie 4.0 platform, the advanced manufacturing platform and MiC 2025 share certain similarities. They are political projects build by consortiums of dominant national industries to address economic problems exacerbated by the 2008-2009 crisis: the stagnation of sales in industrial equipment in a context of growing international competition for Germany; the decline of high-tech industries in manufacturing for the US; the hegemony of Western multinationals on domestic value chains for China. These projects aim at developing and selling new technologies as a mean to create/control new markets and capture state action and resources.

All the three initiatives appear to be built on well-established approaches of industrial policies involving the existing nation innovation system and its traditional political institutions. For these very reasons, these projects are not national versions of similar policies addressing the same technological disruptive transformations, but different sets of industrial policies in terms of players, technologies, stakes and objectives. While these projects have successfully managed to capture state action and to involve companies (in particular in Germany and China), their performativity is still limited by an array of technological, organisational and economic obstacles. The automotive industry provides a good illustration of these limits. Despite the fact that this is one of the most important industrial sectors in all the three countries considered, and by far the most important buyer of manufacturing technologies worldwide, the sector's experiences in these projects show that the technological change is much slower than expected and the prospects for a wider diffusion of industry 4.0 manufacturing technologies in automotive plants remain unclear. In the case of Germany, where the automotive sector is much more involved than in the US and China, most of the experiments under development concern the soft side of the smart factory through the introduction of digital assistance systems such as data glasses, "smart" gloves or "smart" maintenance technologies (Nyhuis et al. 2017; Evers et al. 2019). By contrast, a new wave of automation does not seem to be on the agenda as the actual number of assembly robots in use is actually declining in Germany and the pilot projects of "collaborative robots" only concern some ad-hoc improvements of ergonomically unfavourable tasks and do not represent a threat to employment (Krzywdzinski et al. 2016). In the US and China even these "soft" experiments do not appear to take place (Lüthje 2018; Dincer 2016). In both cases, since the level of automation in the core sectors of the car industry generally is high, there is no significant incentive to implement radically new schemes of digital manufacturing (Pardi et al. 2019).

This does not mean though that these projects are not having any impact on the sector, and in particular on work and employment. But the changes at hand are subtle and much more gradual than the concept of a digital manufacturing revolution suggests. In the case of Germany, widespread experimentations with digital wearable devices might pave the way to the deskilling of maintenance and other forms of technical work. These technologies could be used in fact to provide simple instructions to line workers in order to maintain machines or to execute technical tasks while the intelligence of work would be shifted to data centres (Krzywdzinski et al. 2016). In the US, the post-bailout (of GM and Chrysler in 2009) investments in new numeric control machines supported by national policies towards advanced manufacturing have aimed at destabilizing and weakening the skilled trades in a context of harsh bargaining over the cost of labour and the introduction of extra flexibility (Dincer 2016). The objective here is to increase the productivity of skilled trades by forcing them to operate several machines at once in a more flexible way. In the longer term, this could allow management to operate factories in ultra-flexible manner 24/24 hours and 7 days a week with no extra labor costs. Finally in China, MiC 2025 programs to support investment in digital manufacturing have been mainly used in the automotive sector to push forward the on-going process of automation in Chinese tier 1 and tier 2 suppliers based on conventional technologies and targeting in particular semi-skilled migrant workers to reduce labour costs (Butollo and Lüthje 2017). This process of "catching up" with international standards of manufacturing organization is the result of pressures to reduce labor costs in a context of rising wages and sluggish sales, but does also represent an answer to the limited but successful attempts of organising collective bargaining in some of these companies.

While all these changes do not radically transform work and employment in the automotive sector, they contribute in further weakening the bargaining power of autoworkers through deskilling and might also increase the disciplinary control over work through data collection and analysis. These threats have been already identified in Germany where trade unions negotiate the introduction of these new technologies (Krzywdzinski et al. 2016), but in other countries where unions are less powerful and organised they may result in new forms of work intensification.

5. Conclusion

To measure the degree of performativity of digital manufacturing concepts we have focused our attention on the automotive sector, which is one of the main buyers of such technologies. To assess the possibility for a digital

[3] For a more detailed analysis of these political projects see Pardi et al. (2019).

manufacturing revolution to take place in the automotive sector, we have reviewed the historical evolution of automotive manufacturing technologies focusing in particular on the 1980s-1990s wave of automation. We have shown that previous attempts of automating final assembly have failed because human based teamwork have proved more flexible and efficient in dealing with complex and constantly evolving assembly processes. We have also highlighted that the main reasons behind these attempts in the past are not present anymore: notably important gaps in productivity and quality between leading and lagging firms; and shortages of skilled and unskilled manpower willing to work in automotive factories. The scope for a digital manufacturing revolution taking place in the automotive sector appears therefore limited.

The analysis of the three main "digital revolution" concepts in manufacturing in Germany (Industry 4.0) in the US (advanced manufacturing), and in China (MiC 2025) has supported more than it has challenged our historical understanding of the future of manufacturing in the automotive sector. Industrie 4.0 and the Advanced Manufacturing Initiative appear as traditional political projects driven by consortiums of dominant industrial firms whose aim is to attract public funding to finance R&D efforts and to support market seeking strategies in a context of crisis and growing international competition. The automotive sector is more involved in Germany than in the US, but in both cases there is no evidence of major disruptive breakthrough of completely new technologies and organizational models – the "smart factory" is evolving in small steps. What we have observed are various forms of experimentation with new digital technologies in Germany, and a catch-up modernisation of existing machines in the US. In the case of China 2025, the project has at least the potential of being "disruptive" as it promotes new emerging sectors, but for this very reason the automotive sector is not concerned and the scope here for major jumps towards digital cloud-based manufacturing appears again very narrow due to the already high capital intensity of existing factories and the limited applications of these technologies in mass production.

Our analysis dismisses the idea that a fourth industrial revolution is under way and that a radical disruptive break will take place in the coming years. In the short term, we rather expect a path-dependent evolutionary trend. It is unclear at the current stage, if the new technologies might have a more transformative character on work and employment in the middle- and long-term. But even if we assume some disruptive potential, the full development and implementation of concepts like Industrie 4.0 will be a process of decades and not years.

However, behind the narratives of revolutionary breaks we have noted that more subtle changes are taking place on the shop-floor of automotive factories. These changes can be the direct consequences of the piecemeal introduction of some new digital technologies (in Germany), or the more indirect outcome of manufacturing revolutionary narratives as they create favourable conditions (public subsidies) for replacing existing machines with more sophisticated one (in the US) or for introducing standard cheap robots in small and medium suppliers (in China). What these changes have in common is that they target the same category of workers: the skilled and semi-skilled workers who occupy strategic positions in the labor market and in the power relations in companies. The threat is not only deskilling, but also the segmentation and polarisation of this group of workers as a way to reduce both labor costs and the scope for collective bargaining in a context of already increasing flexibilisation and intensification of work: all the more reason to make of the "future of work" in the digital era a matter of debate, rather than consensus, and of political choices, rather than technological necessities.

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