

**SPECIAL ISSUE PAPER**

# COVID-19, economic crises and digitalisation: How algorithmic management became an alternative to automation

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**Abstract**

The COVID-19 crisis witnessed a major rise in investment in software for the digital organisation and rationalisation of work, while investment in robotics is continuously lagging behind expectations. This article argues that we can understand this development as the continuation of the rise of algorithmic management as a technological fix for profitability crises. Thus, in the face of falling wage rates and a structural overaccumulation of capital since the 1970s, algorithmic management has become an alternative to automation. The article reconstructs the history of algorithmic management in connection to economic crises. This allows for periodisation of the rise of algorithmic management from 'computer-integrated manufacturing' to remote work in four waves. In times of crisis, algorithmic management functions as a substitute for investment in 'tangible capital' such as robots. Structural economic forces thus interact with labour conflicts at the company level, shaping the rise of algorithmic management.

**KEYWORDS**

algorithmic management, automation, COVID-19, crisis, digitalisation, financialization, labour conflicts, labour control, political economy, secular stagnation

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## INTRODUCTION

Digitalisation is probably the single most significant corporate response to the COVID-19 crisis. Yet this trend may be further differentiated: there is a major rise in investment in software for the digital organisation and rationalisation of work (Amankwah-Amoah et al., 2021; McKinsey, 2020), while investment in robotics is stagnating (IFR, 2020, 2021; Krzywdzinski et al., 2022). This article argues that this development is the continuation of the rise of algorithmic management as a technological fix for profitability crises and as an alternative to automation.

Model-based studies predict that the COVID-19 pandemic will lead to an upsurge of automation (Blit, 2020; Chernoff & Warman, 2020). They carry forward a debate on the future of work, which—already before the pandemic—was very much focused on the substitution of work through automation (most prominently Acemoglu & Restrepo, 2019; Brynjolfsson & McAfee, 2014; Frey & Osborne, 2017; for a critical review, see Spencer et al., 2021). As a result, past predictions of a technological end of work were updated once again (e.g., Susskind, 2020). Yet, work shows no sign of vanishing (Spencer, 2018). That these predictions fail to come true is mainly due to their technological determinism, which largely ignores the politico-economic preconditions of technology implementation (Wajcman, 2017). The decisive factor for implementation is not technological feasibility, but the expected profitability of the investment. Global surveys of managers show that the central motive for automation is cost reduction (Tulieres et al., 2019). If this is the case, there are important technological alternatives to automation. This article argues that in the face of falling wage rates and structural overaccumulation of capital since the 1970s, algorithmic management has turned into such an alternative, since it is increasingly attractive for capital.

This article uses a broad definition of algorithmic management, which encompasses the digital direction, evaluation and optimisation of labour processes. In most cases, algorithmic management does not automate management completely but rather augments it. The corresponding technologies can be located at different levels of management, from the control of individual workers to resource planning systems spanning a whole company (Schaupp, 2021c). Yet the latter systems will be considered here only insofar as they affect workers. Several studies have already outlined how algorithmic management transforms the world of work (e.g., Heiland, 2021; Joyce et al., 2019; Lehdonvirta, 2016). However, these studies are very much focused on the so-called platform or gig economy, while algorithmic management is not limited to this sector. This article will show, by contrast, that algorithmic management in a broad sense originated in manufacturing and is continuously spreading across sectors.

The present article makes three main contributions: First, it elaborates the framework of crisis history, which can help identify the agency of capital and labour (and its limits) to shape the dissemination of algorithmic management. This approach also allows for a periodisation of the development of algorithmic management in four waves. All waves are characterised by a new crisis constellation, from the recession of the 1970s to the global coronavirus pandemic. Among the reactions to all of these crises were specific new sociotechnical innovations that aimed to restore profitability. Second, the article demonstrates how these crises are connected to concrete conflicts on the company level, all of which shaped the rise of algorithmic management. Third, it concludes that structural overaccumulation of capital and falling wages contribute to making algorithmic management an attractive alternative to automation—with important implications for the future of work.

The first section of the article elaborates the analytical framework of 'crisis history', while each of the following sections deals with one of the four waves of the dissemination of

algorithmic management. This process arguably took off with the rise of the idea of 'computer integrated manufacturing' (CIM) in the mid-1970s. Only a few years later and along with economic financialization, the second wave of algorithmic management followed; it was characterised by the idea of 'lean production'. Since 2010, the emergence of the 'Internet of Things' provided the possibility of equipping all means of production with networked sensor technology, thus initiating the third wave of algorithmic management. The fourth and current wave began with the coronavirus pandemic and its requirement of 'social distancing'. This led to further acceleration in the algorithmic remote control of work, especially in telework and the delivery sector. The final section of the article recapitulates the analysis to elaborate the relationship between economic crises and the agency of capital and labour in the rise of algorithmic work control.

## Technology and crisis

Since the beginning of industrialised work, attempts have been made continuously not only to rationalise work control (by different forms of organisation) but also to automate it. Computers drastically expanded the automation and augmentation of management in algorithmic work control (Zuboff, 1988). The dissemination of digital technology, however, does not follow a strictly technical logic but is bound to continuous crises in capital accumulation (Schiller, 2014). With this in mind, the current article will examine the connection between the rise of algorithmic management and economic crises from 1970 to 2020.<sup>1</sup>

The emergence of algorithmic management in industry coincides with a global economic turning point: since the mid-1970s, the rate of reinvestment of profits in fixed capital has been decreasing steadily (Durand & Légé, 2014). In light of this, Aaron Benanav (2020) has shown that economic indicators point toward a decline rather than an increase of investment into automation technology. A surge in automation would be visible in the growth rates of capital stock and productivity. Yet both are declining continually in developed economies (see Figures 1 and 2).

Critical political economy has attributed this lack of investment to a crisis of capital overaccumulation (Harvey, 1990; Nachtwey, 2018). This means that while present-day profits may be high, the realisation of future profits appears uncertain, which keeps firms from expanding their infrastructures—a tendency that gets proportionately stronger with a growing concentration of capital. This phenomenon has turned into a structural crisis of capital overaccumulation across all core capitalist countries, albeit in different phases (Bischoff et al., 2018). David Harvey argues that the roots of overaccumulation cannot be eliminated within the capitalist order: 'The only question, therefore, is how the overaccumulation tendency can be expressed, contained, absorbed, or managed in ways that do not threaten the capitalist social order. We here encounter the heroic side of bourgeois life and politics, in which real choices have to be made if the social order is not to dissolve into chaos' (Harvey, 1990, p. 181).

One of those choices is investment in 'intangible capital'.<sup>2</sup> This segment of capital has been an exemption from the general decline of investment and, subsequently, has been growing

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<sup>1</sup>Such a crisis history must necessarily adopt an international perspective, as neither global economic crises nor the development of means of production can be isolated in a single country. The focus of this article is on the early-industrialised economies.

<sup>2</sup>Intangible capital includes R&D, patents, software and organisational developments like lean production.

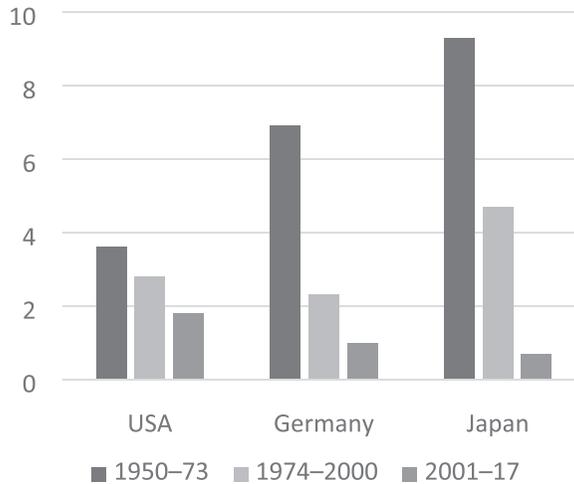


FIGURE 1 Capital stock growth rate. *Source:* Benanav (2020); own depiction.

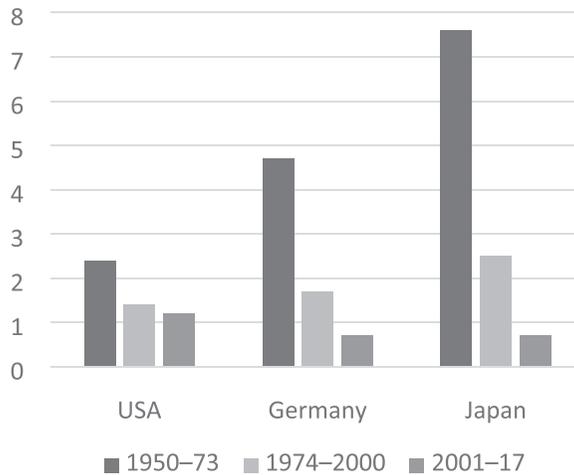


FIGURE 2 Productivity growth rate. *Source:* Data from Benanav (2020); own depiction.

much faster than tangible capital, that is, machines and facilities (Crouzet & Eberly, 2019). Haskel and Westlake (2018, p. 26) have shown that in the European Union and the United States, intangible investment overtook tangible investment during the financial crisis. The gap has continued to widen since then. This development has been attributed to the fact that intangible is more easily scalable and is less excludable than tangible capital (Crouzet & Eberly, 2019, p. 4). Thus, the use of intangible assets enables firms to increase market power and profitability without generating a corresponding increase in fixed capital investment (Orhangazi, 2019). The economic discussion on intangibles is vast. Here it will be limited to one important part of this larger category: business software.

While algorithmic management is always connected to physical devices, its genuine innovations are mostly within the realm of software. Haskel and Westlake (2018, p. 18) even claim that "This is not so much innovation, but *innervation*—the process of a body part being

supplied with nerves, making it sensate, orderly, and controllable'. Because algorithmic rationalisation of the processes of production is cheaper and more flexible than advanced automation infrastructure, it aligns with the requirements of avoiding too much capital fixation and increasing profitability. Accordingly, the proportion of investment in intangibles correlates with capital concentration, suggesting that intangible capital functions as a substitute for tangible capital (Crouzet & Eberly, 2019). These data indicate that the growing importance of algorithmic management over automation may be a symptom of overaccumulation. While some theories of overaccumulation merely deduce concrete economic ruptures from a general law, this article develops a framework that conceptualises a complex relationship between global economic crises and the collective agencies of capital and labour.

Richard Edwards (1979) developed a new classical approach that posits the appropriation practices of workers as an important factor in the development of workplace technologies. In his understanding, these are shaped by both the nature and outcome of the workers' struggles: 'The workers' militance created a crisis of control within the firm, a crisis that revealed the flaws in the existing organisation of work. Even though the workers were defeated, the corporations took notice, for after the immediate crisis had passed, corporate capitalists had to deal with the chronic causes underlying the crisis' (Edwards, 1979, p. 49). Edwards sees 'crises of control' as one of the most important motors of the development of new management technologies. In this sense, empirical studies have shown how a successful implementation of new forms of managerial and technological work control depends on the strength of labour unions (e.g., Link & Siegel, 2002).

Silver (2003) has transferred this approach to the macro-level. She argues that labour disputes which lead to less favourable conditions for the utilisation of capital can turn into a viable crisis factor. The reactions of the capital to such crises are an essential motor for the continuous transformation of the sphere of production. Silver calls these reactions 'fixes', and distinguishes among them 'product', 'financial' and 'technological' types (Silver, 2003, p. 39). Although the various fixes are usually intertwined, the technological fix is, of course, central here. In Silver's case, the term refers to both technical innovations (such as the assembly line, which allows mass production and easier control of work at the same time) and organisational transformations (such as the management system of lean production). On the one hand, Silver's schema indicates that technical and organisational measures form a unit in the rationalisation of production as well as the control of labour. On the other hand, it underscores that technical developments in capitalist production are always tied to further dynamics of crises and conflicts, which is why the design and dissemination of technology are historically contingent (see also Noble, 2011).

Edwards and Silver conceptualise innovations of control as direct reactions to crises of profitability. However, as we will see in the following sections, the relationship between crisis and technology dissemination is usually not necessarily a direct one. While economic crises are the indirect result of dispersed accumulation strategies, they cannot be addressed by collective actors on the side of capital or labour. Instead, to them, they are *external forces*, which cannot be controlled but may initiate certain strategic actions. Thus, the technological fixes described in this article do not resolve any crises; they do not even aim to address them. This is because economic crises relate to a separate level of society, which is incommensurate with the company level as the main arena of negotiating the implementation of technology. This article, therefore, proposes that there is an indirect relationship between economic crises and the agency of capital and labour in shaping technology at the workplace. Such a perspective

integrates an emphasis on structural forces such as overaccumulation and the collective agency of concrete fractions of capital and labour, which cannot be deduced from these structures.

Although this article will refer to various concrete examples of technological projects, the aim is not so much to reconstruct individual motivations behind technology-related decision making, but rather to examine the relationship between these technological projects and the power relations between capital and labour. This focus on the capital-labour relation, in turn, is not to deny that digitalisation is also influenced by other factors. Part of the rationale of the latter stems from the capital-capital relation, that is, capital's aim to increase flexibility to reach new markets, to add digital services to products, and so forth (Haskel & Westlake, 2018). Furthermore, the state is a very important actor in the development and dissemination of technology (Mazzucato, 2015) but it will be addressed here only peripherally. Instead of identifying a singular driving force behind the development of algorithmic management, the goal of this heuristic is to raise theoretical awareness of the connection between this development and conflicting socioeconomic dynamics. It will serve as an analytical framework for the following sections, which take a more detailed look at the development of algorithmic management.

## **Computer-integrated manufacturing (ICM) and the threat of automation**

In the course of the global oil crisis of 1974 and the subsequent stagflation, economies all over the world experienced the worst recession in postwar history. The world's 24 richest countries saw their growth rates drop from 5% to 0% (Moody, 2007, p. 12). The crisis was followed by a massive boost in the technical rationalisation of production, which entailed especially a surge in automation, achieved by using early forms of robotics and digital production control. This linked automation and computerisation, and the computer became an organisational technology in the production process (Zuboff, 1988). Thus, the vision of CIM was developed, according to which not only the material production was to be taken over by robots, but also the control of plants was to be automated and digitalised. By the mid-1980s, a genuine CIM-euphoria had spread to continental Europe. At its centre was the vision of a completely controllable factory—a radical automation of both planning and manufacturing within a deterministic system of hierarchical control.

This hierarchy of algorithmic control was formalised in the 'automation pyramid' (Siepmann & Graef, 2016, pp. 49–53). At the top of this pyramid is the enterprise resource planning system (ERP), through which the use of personnel, material, machines and the like is planned. Incoming orders are divided automatically into smaller orders and requirements, which are in turn passed on to the subjacent control level of the manufacturing execution systems (MES). These process-related control systems are directly linked to the plant control system and thus enable real-time managing and controlling of production. The lowest level of the pyramid is supervisory control and data acquisition (SCADA)—the direct control of individual production processes. It includes direct execution commands to a production machine, but also technical control of individual human workers (Schaupp & Diab, 2020).

With this model, the advocates of CIM (mainly management consultancies) promised the elimination of a range of uncertainties in production. Besides reducing machine downtime or errors, the main aim was to eliminate human labour as a source of disruption—by removing it from the production process. Misbehaviour and disobedience of individual workers always

posed a threat to highly rationalised production processes (Ackroyd & Thompson, 2022). But in the 1970s, a global wave of mass strikes by organised industrial labour endangered capital accumulation across this sector (Cowie, 2010). In the Western European automotive industry especially, demand could regularly not be met due to production downtime caused by strikes (Hessler, 2014, p. 63). Consequently, those workers who could not be replaced were subjected to a regime of continuous computer control (Ebers & Lieb, 1989). On the level of the labour process, production machines became computer-controlled. On the managerial level, ERP systems were used to coordinate and optimise the production process. Empirical studies imply that this contributed to a polarisation in the organisation of work (Goos & Manning, 2007): while computer-controlled machines were designed to substitute for skilled labour, engineers would act as 'technical virtuosos,' watching over the system, further developing it and correcting its errors. In this sense, the empirical reality of CIM was characterised as 'computer-aided neo-Taylorism' (Lutz, 1990).

However, a decade after the beginning of the CIM euphoria, the grave disappointment of equal magnitude manifested itself. Even as many companies had invested huge sums in new computer infrastructure, the leaps in productivity it promised had not materialised. The complete digital representation of production processes proved impossible, especially since the networking of the various systems could not yet be realised (Dolata, 1988). Above all, resistance began to emerge from the labour unions in a variety of ways against the job cuts associated with automation (Ebel, 1990; Hessler, 2014). The combination of these factors led to CIM being considered a 'miserable failure' (Brödner, 2015, p. 239) according to the assessment of actors involved at the time.

In terms of the relationship between crises and the agency of capital and labour in the implementation of technology, this first wave of algorithmic management provides an important lesson. While the stagflation of the 1970s was the result of capitalist accumulation strategies, its causes were clearly beyond the control of individual capitalists. The 'technological fixes' described in this section thus transferred the problem to the level of capital-labour relations by responding to the gains of industrial workers. However, when CIM had to prove itself in practice, visions of full automation were soon abandoned as the rate of investment in fixed capital began to revert to tendential decline after a peak in 1974 (Brenner, 2006; Durand & Légé, 2014). From this time on, the direct connection between automation and algorithmic management was severed. It was not the automatic factory itself—which had survived the demise of CIM as a managerial fashion—but rather computer-controlled machines and ERP systems which would grow in importance, as we will see below.

## **Financialization and lean production**

The technological fixes of the 1970s could not restore profits to precrisis levels. Therefore, they were complemented by increasing attacks on the social conditions of the Fordist production model, the complex institutional regulation of the economy combined with a network of welfare state security mechanisms. These institutions were now perceived as an obstacle to capital accumulation and were therefore undermined in the period of the global triumph of neoliberalism (Jessop, 1991). The erosion of the Fordist production model led to a steady decrease in wage rates as well as a demise of social security systems. Since the 1980s, wages in all OECD countries shrank in relation to labour productivity. In Germany and the United States particularly, this ratio is extreme (Ugucioni & Sharpe, 2016).

Taken together, these developments caused a slump in consumer demand in the Western world, which contributed to making the future amount of product sales uncertain. Such uncertainty resulted in a continuous worldwide decline in the so-called gross investment ratio, that is, the proportion of profits that are reinvested in capital. In a sense, there was an excess of capital (Brenner, 2006; Nachtwey, 2018). In the face of falling profits in production, surplus capital was increasingly invested in financial markets instead of the expansion of productive technology (Orhangazi, 2008). In the 1990s, the global financial economy grew to unprecedented dimensions. The scope, but above all, the speed of financial transactions, increased enormously. This required a global digital infrastructure that could shrink space and time as much as possible, which in turn created one of the most important initial sources of the demand for a digital infrastructure (Schiller, 1999).

Financialization also led to the restructuring of corporations themselves; a large part of turnover and profits shifted to financial markets. This development also affected production. A focus on shareholder value was widely enforced, which above all meant a shift of market boundaries into the companies (Brinkmann, 2011). The central transmission mechanism of this shift was the paradigm of 'lean production'. Originating from the Toyota production model, lean production was intended to enhance product quality and production flexibility (Bertagnolli, 2018; Womack et al., 1990). Efficiency gains were to be realised through the elimination of 'waste' in the dimensions of time, material and labour. Silver (2003) has identified lean production as both a technological and a spatial fix.

In technological terms, through the analysis of labour processes, 'dead times' were to be eliminated, while simultaneously, workers were made accountable for the continuous improvement of the production process (Moody, 1997). Since the 1990s, most companies introduced new digital technologies to measure the labour process by means of 'key performance indicators' (KPIs), which are used to gather data on workers (Taylor, 2013). These numeric performance indicators made it possible to transfer investor goals onto workers (Ezzamel et al., 2008). For the labour process, this meant an intensification of work in both quantitative and qualitative terms, as work was not only sped up but tacit skills and knowledge were increasingly demanded (Thompson, 2013). Even though the lean paradigm originated in the automotive industry, its technologies of performance measurement quickly spread to other sectors. They became especially formative for the labour process in call centres and from there spread to nearly all areas of white-collar work (Bain et al., 2002). Today, 'lean methods' are employed in the administrative sector, the related 'Kanban principle' is used in fast-food restaurants, 'store floor management' is operative in banks, 'Obeya' used for merchandise trade, 'fast set-up' common on construction sites, 'value stream analysis' is ubiquitous in zoos, and so-called 'cardboard engineering' is common in hospitals (Bertagnolli, 2018, p. 5). The term 'lean' was rapidly adapted for use in the description of any kind of continuous process of optimisation and flexibilization.

The central organisational instrument for achieving flexibilization was self-organised teamwork. In this way, mutual support—but also mutual control—via teams promised to replace elements of middle management. Where responsibilities and processes were once previously defined by hierarchical positions and departmental boundaries, now flexibility potential was being sought in teamwork and independent company units or 'profit centres' (Pongratz & Voß, 1997). Empirically, the functional flexibility demanded by the lean production model had a powerful impact on industrial work organisation. Most companies reacted to this requirement, as Toyota had already done, first by reducing staff and second by using instruments of 'flexible' personnel deployment. In concrete terms, this usually meant an

increase in temporary work. Thus, production on demand was followed by work on demand (Moody, 1997).

For production infrastructure, flexibilization meant a shift away from automation systems spanning a whole plant toward one of decentralised layouts. This was a countermovement against the aim of 'integration' of all processes into a unified computer-controlled system, which had been central for CIM. In some cases, flexibilization also appears to have been used to reduce the growing disruptive capacity of workers in highly vulnerable integrated automation systems. For example, in 1986, workers at a John Deere tractor plant in Waterloo, United States, claimed redundancy protection in the face of CIM. A strike in one part of the plant led to a shutdown of all production due to the high degree of technical integration. The event led management to restructure the plant along the lines of decentralised 'cellular manufacturing' (Ebel, 1990, p. 68).

Such technological fixes were tightly connected to the spatial fix. According to the just-in-time (JIT) imperative, products were only to be manufactured or transported when there was a concrete demand. The removal of the product at the end of the process chain was supposed to automatically trigger the information to reorder the same product at the beginning of the chain ('pull'). The development of ERP systems consequently changed from managing a single plant (as in CIM) toward a systemic rationalisation of the entire supply chain (Altmann & Deiß, 1998). This was the technological basis for the development of JIT as an important component of the lean paradigm. Based on the Internet, value chain analysis began to encompass production processes all over the globe (Bruun & Mefford, 2004). Subsequently, ERP systems continued to evolve, combining ever more data to synchronise and optimise processes along the value chain. Such global resource planning and value chain analysis technologies created new opportunities to outsource individual work steps and were used to distribute production processes globally. The intensified competition among workers it detonated has contributed to the falling wage rates at a world scale (Huws, 2003).

Yet neither the technological nor the spatial fix succeeded in themselves in weakening the bargaining power of workers. Lean supply chains also resulted in new vulnerabilities. The JIT imperative eliminated all resource buffers to reduce storage costs and reaction times in light of market volatilities. This largely increased the disruptive power of workers, because a strike at a specific 'choke point' could hold up the supply chain in its entirety (Alimahomed-Wilson & Ness, 2018; Silver, 2003).

In sum, lean production brought forward a second wave of algorithmic management insofar as it relied on certain types of digital technologies: digital performance measurement systems at the level of the labour process, and expanded ERP systems for global value stream analysis at the managerial level. Like the former, this second wave of algorithmic management demonstrates a complex relationship between the dissemination of technologies, economic crises and the agency of capital and labour. We have seen that in light of overaccumulation, the capital shifted from production to finance. At the company level, control innovations in performance management and ERP systems functioned as transmission mechanisms of shareholder value in production. Internal and supply-chain-based flexibilization also functioned as a technological and special fix to reduce the bargaining power of workers. However, JIT production supported by digital value chain analysis did not eliminate but rather expanded the disruptive capacity to whole supply chains.

## Postgrowth capitalism and new algorithmic work control

In the financial economy, derivatives and other instruments of speculation made it possible to profit without actually producing and selling goods. In a sense, capital was betting on the risks of its own cycles, which created the illusion that value could be generated without labour. This wager was proved wrong in dramatic fashion when the subprime bubble burst in 2008 and set off a crisis that shook the entire world economy (Dyer-Witheford et al., 2019, p. 143). Even in the aftermath of this global economic crisis, the ongoing overaccumulation crisis of capital still constrained investment in the material production of goods. On the one hand, equipping production facilities with new technologies, especially robotics, is rather expensive; on the other hand, in contrast to the financial markets, invested capital is fixed for a long time and is, therefore, particularly prone to crisis. In view of permanently low growth rates, many companies continued to refrain from major industrial investments. Thus, after the global financial crisis, the major countries were not able to significantly boost economic growth. Even in phases of economic boom, GDP growth in highly developed capitalist economies ranged between 1.5% and 1.8%—with a trend toward a secular stagnation (Galbraith, 2015), which led to the diagnosis of a 'postgrowth capitalism' (Nachtwey, 2018).

Salvation was once again seen in digitalisation. Thus, in the mid-2010s, nearly all high-tech economies launched state-sponsored programs to promote digital rationalisation. A few years later, these programs were relaunched under the now more popular term of 'artificial intelligence' (AI). In the United States, the National Artificial Intelligence R&D Strategic Plan was drafted in 2016. China announced the 'Next Generation Artificial Intelligence Development Plan' in 2017. One year later, the EU announced its plan to increase investment in AI research by at least €20 billion by 2020 (Dyer-Witheford et al., 2019, p. 40). These programs may be interpreted as techno-political responses to the financial crisis on the state level (Frey & Schaupp, 2020).

The technological innovation behind this third wave of algorithmic management was the paradigm of the 'industrial internet of things' (IIoT). This paradigm aims to link all corporate 'things' and processes as well as entire supply chains and connect them to control systems. These control systems are then linked to global monitoring and management systems. The main innovation is that the hierarchical control model of the automation pyramid, which was characteristic for CIM, is turned into a multi-directional feedback system. Thereby, the previously separate control levels now form an integrated network. However, contrary to the integration model of CIM, the IIoT paradigm aims for flexible adaptability in the sense of cybernetic self-organisation (Schaupp & Diab, 2020).

The microlevel of such a system is constituted by the control of an individual machine or worker. Traditionally, work control systems consist of a screen through which detailed visual instructions are given to workers. Further developments are now partially replacing this interface with technologies that are closer to the body, so-called 'wearables' (Moore, 2017). The IIoT allows to connect such work control systems to meso-level control systems to create a feedback loop between resource planning and labour process (Schaupp & Diab, 2020). An example for a meso-level system of algorithmic management would be *KapaflexCy*, a digital system for personnel resource planning, which semiautomatically allocates workers to specific tasks based on the data available on them.<sup>3</sup> A report by the research team which developed this

system (Bauer & Gerlach, 2015) justifies its necessity by explicit reference to stagnating growth rates after 2008. The authors indicate, furthermore, that they expect an increase in market volatility as a result of the trend toward individualised production in the digital economy. *KapaflexCy* promises to address these problems by offering additional flexibility in personnel deployment. This is a prime example of Silver's technological fix to profitability crises.

On the macrolevel of algorithmic management, ERP systems have evolved into cloud platforms, which consolidate process optimisation along the whole supply chain, down to the individual machine. For example, Volkswagen (2020), together with Amazon and Siemens, has developed an industrial cloud, which integrates data of all production systems from every VW factory around the world. Moreover, the corporation's suppliers will be able to integrate their own data via platform interface to synchronise and optimise the whole value chain. Yet there are various accounts of 'algoactivism' (Kellogg et al., 2020) or 'technopolitics from below' (Schaupp, 2021c) in which workers contest the new forms of algorithmic control. In some cases, this leads to the alteration or even abandonment of projects.

Thus, while automation is featured prominently in the discourse of 'Industry 4.0', most of its genuine innovations are intangible. Consequently, the growth of the investment share in intangible capital has accelerated since the financial crisis (Haskel & Westlake, 2018), while the share of tangible capital, including robotics, has tended to decline (Moody, 2018). This dynamic is also reflected in the promise of digitalisation initiatives in manufacturing to 'reshore' jobs from low-wage countries (Coons, 2019). In Germany, the 'Industrie 4.0' initiative has explicitly turned away from the visions of full automation, which were still dominant in CIM. This can be partly attributed to the fact that German trade unions have been involved in the implementation of 'Industrie 4.0' from the beginning (Haipeter, 2020).

Thus, the third wave of algorithmic management did not emphasise automation but instead the rationalisation or even reintegration of human labour as algorithmically controlled low-skilled labour. In this sense, managers in manufacturing explicitly point to algorithmic management as an alternative to automation (Schaupp, 2021b). Haskel and Westlake (2018, p. 191) conclude that 'part of the reason for the perhaps unexpected growth in [...] very nonautonomous work is that the intangibles of organisational development and software enable more and more effective monitoring'. The current instantiation of algorithmic management has been enabled by a prior global employers' offensive, which reduced labour costs by means of precarious employment contracts and low wages (Standing, 2011). In many cases, human labour is actually now cheaper than robots and also more flexible. Such flexibility entails both the possibility of simply firing temporary workers when they are no longer needed as well as the option of moving human labour between different workplaces when products change or when other innovations occur. Robots could not adapt to such developments.

Studies have shown that the IIoT paradigm radicalises primarily the principles of lean production (Butollo et al., 2019) and that higher adoption levels of Industry 4.0 were more likely in companies that had extensively implemented lean production practices before (Rossini et al., 2019). The JIT imperative especially was radicalised as so-called 'just in sequence' (JIS): parts are to be delivered not only at the time they are needed but also in the exact order in which they are used. This protocol has also, however, increased the capacity of workers to disrupt tightly integrated supply chains. One example of this is the 1-week strike at a

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<sup>3</sup>The extent of this automation was subject to negotiations within companies as German works councils have the right to codetermine workforce allocation (Schaupp, 2021c).

Volkswagen plant in Győr, Hungary, in January 2019. Due to heavy supply-chain integration, the strike stopped production in several automobile plants and won the workers an 18% rise in basic wages (Horváth, 2019). Nevertheless, technological fixes were soon applied. They aimed to keep workers at a distance from companies while maintaining close control over them.

## Coronavirus and remote control of work

COVID-19, the World Bank (2021, p. 3) stated, 'caused a global recession whose depth was surpassed only by the two World Wars and the Great Depression over the past century and a half. The recession was accompanied by losses of 8.8 percent of global working hours in 2020 relative to the fourth quarter of 2019, the equivalent of 255 million full-time jobs, and quadruple the losses of the 2008 crisis. Global labour income declined by 8.3% (ILO, 2021).

The crisis also worsened the effects of the pre-existing secular stagnation as described above. According to the World Bank (2021, p. 128), the global contraction in investment in 2020 was 'considerably sharper than during the global financial crisis'. Over the year 2019, investment in industrial robotics had already dropped by 12% globally in the face of economic downturn and trade tensions (IFR, 2020). For the first half of 2020, year-to-date numbers show a decline in robotics investment by 18 percent (Demaitre, 2020; see also Xiao, 2020). For the whole year of 2020, the growth rate of robot installations was below 0.5% with 71% of all newly deployed robots installed in Asia (IFR, 2021). A study of five leading companies in the global apparel industry found none of the companies embracing automation as a result of Covid. All respondents noted the reluctance of suppliers to make big investments in technology and their fear of decreasing flexibility. Interviewees in all companies agreed, however, that significant job losses in production are unlikely (Barcia de Mattos et al., 2021). For the US context, a model-based projection has concluded that in the long term, Covid will decrease the rate of workforce automation (Shutters, 2021). While it is too early to draw definite conclusions, predictions of a new wave of automation in the wake of the pandemic (Blit, 2020; Chernoff & Warman, 2020) do not seem to match empirical data.

Already in the decades before the pandemic, the decrease of investment in productive capital did not only contribute to financialization but also to a shift of jobs toward the service sector. It was specifically this sector, which was hit the hardest by the virus and the subsequent lockdowns. This meant that in high-tech economies such as the United States, a more than a third of the workforce employed before the pandemic was shifted to remote work with office workers being the most likely to experience such a shift (Brynjolfsson et al., 2020). While some managers feared losing control over their staff in home office, others announced that they wanted to keep a high level of remote work after the pandemic, assuming reduced infrastructure costs as well as constant or even increased work productivity (McKinsey, 2020). On the side of labour, some European trade unions have also argued for a right to remote work (Meyer, 2020). An international survey among home office workers shows that most of them believe the pandemic to accelerate the digital transformation and that they will work exclusively 'digitally' even after the pandemic (Nagel, 2020). The effects of this development cannot yet be fully evaluated. Research from before the pandemic suggests that while remote working is associated with higher satisfaction and job-related well-being, it also comes with work intensification and a greater inability to 'switch off' (Felstead & Henseke, 2017).

The technological basis of this shift to remote work is a fourth wave of algorithmic management, which promises to close the control gap in remote work, mainly via digital

surveillance (Faraj et al., 2021). A recent global survey has shown that the demand for employee monitoring software increased by 87% in April 2020 compared with the monthly average before the pandemic. Long-term demand is expected to stabilise at 58% above its prepandemic level (Migliano, 2021). Generally, the consensus seems to be that accelerated digitalisation is *the* central reaction to the crisis (Amankwah-Amoah et al., 2021) with 'digital collaboration' and supply chain management the most important areas of investment (Barcia de Mattos et al., 2021; McKinsey, 2020). Yet the bulk of investment takes place in companies that are already heavily digitalised while the distance of those lagging behind is growing (Krzywdzinski et al., 2022).

Software such as Zoom, Slack or Microsoft Teams, is predominantly designed to allow for digital collaboration, yet it also facilitates advances in algorithmic management. This is due to the fact that all communications in these channels are documented in meta-data. Virtual private network login times reveal if employees have started work late. Server-side timestamps detect if someone spends an unusual amount of time in a specific portal, and second-counts of total talk time per speaker in Zoom show who was the quietest in a meeting. These data can be combined with other sets such as employee turnover or performance measures to inform managers: 'Although many companies were ready to analyze data at scale, they didn't have enough of it to analyze because most employees' actions were not recorded and stored. COVID-19 solved that problem' (Leonardi, 2020, p. 3). As international and national privacy regulations prohibit the automated analysis of individual performance profiles in many regions, such analysis primarily takes place at the team level.

In contrast to most other sectors, platform companies profited from the crisis. In the United Kingdom, the food delivery service Deliveroo almost doubled its customer base by delivering consumer goods from supermarkets. In the United States, Amazon aimed to hire 100,000 new delivery and warehouse workers to cope with the exploding demand, but also to disrupt a growing wave of strikes. In the locked-down cities of Paris and Milan, bike couriers for the food delivery services were often the only people left in the empty streets (Altenried et al., 2020). The pandemic thus accelerated a pre-existing tendency of platform work to outsource and commodify domestic labour such as cooking (Huws, 2019).

Much has been written about the platform economy and its deteriorating effects on working conditions (e.g., Heiland, 2021; Joyce et al., 2019; Woodcock & Graham, 2020). The most important aspect for the purpose of this article is that the central technological basis of its business model is algorithmic work control: only the possibility of the 'remote control' of workers enables the spatial and organisational decoupling of workers from the company. In the delivery sector, this takes the form of navigation systems, which direct workers through the space of the city or the warehouse and track their behaviour at the same time (Heiland, 2021). This remote control may be referred to as 'delocalisation' (Lehdonvirta, 2016). It seems to be exactly this aspect of the delocalisation of work that makes delivery platforms so successful in periods of 'social distancing'.

In contrast to automation, new forms of algorithmic management do not only aim at the expulsion of human labour—in the form of qualitative and quantitative rationalisation—but also at its devalued *reintegration* (Schaupp, 2021b). Detailed digital instructions allow for the hiring of unskilled labour. Many platform companies rely especially on employing migrants, who do not have to speak the local language because they are directed via algorithmic management (Schaupp, 2021a). This makes it possible to reduce labour costs, which in turn makes highly labour-intensive business models—such as food delivery via bicycle—economically feasible in the first place.

Overall, companies have reacted to the Covid crisis with a major shift to remote work. The process of delocalisation this set in train created a crisis of control, which in turn contributed to the further dissemination of algorithmic management. While the applied technologies have all been available for some time, the Covid crisis dramatically accelerated their dissemination, and precipitated a fourth wave of algorithmic management—even before the third wave had been fully rolled out. Yet, in light of the previous sections, employees should be expected to react to the new forms of control, and the practical use of the new digital infrastructures is unlikely to mirror managerial intentions exactly (Faraj et al., 2021).

If the financial crisis of 2008 appeared to be beyond the control of all individual or collective actor, the Covid crisis—as ‘natural disaster’—was characterised even more definitively by this quality. However, the velocity and severity of the pandemic has been in part due to dangerous practices of organising work: companies’ refusal of health measures and their heavily globalised business networks (Bapuji et al., 2020). These managerial practices sparked a global series of workers’ struggles for which new ‘fixes’ are likely to follow in response (Azzellini, 2021).

## CONCLUSION

While the pandemic has once again provoked speculation about an upsurge of automation, the arguments presented here point in another direction: algorithmic management gained importance as a central means of increasing profitability, especially when compared to automation technology. This article has argued that the increase in the relative importance of algorithmic management is to be explained structurally by as part of the crisis of overaccumulation which has afflicted the global economy in various forms since the 1970s. While global rates of investment in fixed capital as a whole are continuously declining, the investment ratio of intangible capital—among them software systems of algorithmic management—has grown since the turn of the millennium and especially since the 2008 financial crisis. Software-based rationalisation also increases profitability but it is cheaper than investment in advanced production infrastructures and can be applied more flexibly.<sup>4</sup>

Algorithmic management thus serves as an alternative to automation, especially in places of high capital concentration. This does not mean, however, that the two are mutually exclusive. A considerable part of the enterprise of software development responds to the need to steer more complex automated production systems. Thus, automation does have effects on labour markets, but the theoretical considerations laid out here imply that the future of work in the digital era will not be characterised by an end of work. Algorithmic management especially serves as the technological basis for new, highly labour-intensive production processes, as in delivery platforms. By overcoming language barriers and simplifying labour processes, such platforms extend the pool of available labour and put downward pressure on wages. Their use makes automation uneconomical by comparison in many cases—and will likely thwart further investment in robotics.

Yet the rise of algorithmic management is not only shaped by politico-economic structures. Macrolevel phenomena, such as the trend toward financialization and its crises after the burst of the subprime bubble, or the global coronavirus pandemic, interact with conflicts on the

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<sup>4</sup>Software systems—especially in ERP—do create path dependencies, but can be applied to various production settings or products.

corporate level in giving rise to specific technological fixes. We have seen how the drive to automation and digital control in CIM served as a means for eliminating contingencies in labour. Later, however, organised labour was seen as a threat even and especially in highly automated production processes, and informed the switch to a more decentralised and flexible production model associated with the lean paradigm. The digitally managed JIT supply chains of the lean model in turn created choke points at which strike action could halt production beyond a single plant. The potential for work stoppage was expanded once supply chains became more integrated via the global IIoT. Finally, the coronavirus pandemic was accompanied by a further rationalisation of work by means of algorithmic remote control of labour processes, which in turn has contributed to a global wave of labour disputes.

Economic crises are important hinges between the dissemination of technology and the social relations of production. Through various mediations, they both shape and are shaped by the agency of capital and labour. The interaction of macroeconomic developments and concrete social conflicts—not mere technological potentials—will shape the future of work.

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## CONFLICTS OF INTEREST

The author declares no conflicts of interest.

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