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Technology upgrading and labor degrading? A sociological study of three robotized factories

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Abstract
In recent years, the technology-driven industrial upgrading in China has resulted in human labor being replaced with robots. This article explores the impact of "intelligent manufacturing" on workers from the following two perspectives: labor relations and the labor process. The authors argue that workers on the shopfloor are experiencing some forms of labor degradation due to robotization, i.e., more flexible labor relations, deskilling, and strengthened technical control. Such a corporation-led and machine-centered industrial upgrading is driven by state policy, capital, and the labor market.

Keywords: Robotization, Intelligent manufacturing, Labor process, Deskilling

Introduction

A new round of technological revolution is triggering a new industrial revolution on a global scale. Digitization, artificial intelligence, the Internet of Things (IoT), big data, and cloud computing have become the keywords of this round of industrial revolution. China is now in a critical period of manufacturing transformation and industrial upgrading. The original equipment manufacturing (OEM) model that has been in existence for more than 30 years has repeatedly withstood the collateral effects of economic crises in European and American countries. The disappearance of the demographic dividend has greatly weakened China's comparative advantage as a "world factory." Frequent labor conflicts hinder the country's social stability and harmony. In this context, the Chinese government has proposed "intelligent manufacturing" as the macro-objective of industrial upgrading, aiming to transform its developmental path through technology-driven industrial upgrading. According to the macro policy on manufacturing development formulated by the State Council, China will continue to upgrade as a major manufacturing country and enhance the overall competitiveness of the manufacturing industry. The government regards intelligent manufacturing as the main direction of manufacturing the next two decades. Intelligent equipment and smart production lines, such as those utilizing industrial robots and automated high-end computer numerical control (CNC) machine tools, are listed as key development areas.

As China is striding toward intelligent manufacturing, we have also noticed the "double-edged sword" effect of technology. On the one hand, technology-driven changes in modes of production can accelerate industrial transformation and upgrading, promote labor-intensive industries to capital and technology-intensive, and replace demographic dividends with technological dividends. Whether it is the rising labor cost faced by employers or the labor rights abuse that workers are concerned about, it seems that they can all be solved with the help of technology upgrading. On the other hand, technological progress has also caused many social problems, such as the technological unemployment caused by robotization, changes in the labor force structure and skill structure, the placement and reemployment of low-skilled workers, and the transformation and governance of labor relations. Because these phenomena have only appeared in recent years and are still developing, the above problems are not yet fully understood and have not been studied in terms of the sociology of labor. Although some researchers have carried out a number of empirical studies (Huang and Sharif 2017; Butollo et al. 2018; Xu 2019), these studies are still in the exploratory stage, and little is known about the changes that have taken place in the workshop. In this context, this research will discuss the impact of the "intelligent manufacturing" technology upgrading process on workers from two aspects: changes in labor relations and the labor process. These two aspects also point to a core issue: whether technology upgrading will bring about labor degradation. Data in this article is drawn from the authors' participatory observations in factory workshops, supplemented by in-depth interviews.

Sociological implication of technological changes

In the history of industrial technology evolution, the social impact of technological change has always been a concern to Western scholars, and many theories and factions have been formed in the research over the years. Liker and his colleagues (Liker et al., 1999) divide these theories and viewpoints into the following four paradigms: technological determinism, management of technology, interpretivism, and political interests represented by labor process theory. The first two focus on technology, while the latter focus on the social context of technological development and the economic and political benefits. Neither interpretivism nor labor process theory agrees that technological development is natural and neutral. As the labor process theorist Thompson (1989) pointed out, technological innovation should not be regarded as a natural process triggered by technological progress but as a continuous improvement in the mode of production centered on capital accumulation, with its social attributes embedded in the antagonistic relationship between the bourgeoisie and the working class.

Most of the economic research on technological change focuses on the relationship between technology and unemployment, and the current research in China on "robots replacing humans" is also concentrated on the labor substitution effect of robots (for related research, see Cheng et al. 2018; Lü and Hao 2018; Zhang 2018). Although all companies that implement the "robots replacing humans" scheme reduce workers to varying degrees, this article does not intend to use quantitative research to test whether new technological changes have caused unemployment. This article attempts to use qualitative research methods to discover how machines replace people, explore how the mode of production and the power relation on the shopfloor change by replacing people, and finally, answer what kind of changes technology has brought to nature of labor. Skills and labor control in the labor process are the two most important analytical perspectives. Next, the authors will take labor process theory as the main path, supplemented by other theories and viewpoints, and review the sociological implications of technological changes.

Technology and skill level

Whether technological progress has brought about "deskilling" or "upskilling," there have always been two parties on this issue, and the debate has continued for many years. Braverman (1979), a representative of the "deskilling" view, proposed that the change of production technology and production process brought about the "separation of conception and execution"; that is, the knowledge and technology in production are transferred to the engineers and managers who design the production process, and the labor control and skill level of workers are greatly weakened. Noble (1984), an industrial social historian, started from the perspective of "social choice" and emphasized the historical role of managers and governments in the decision-making process that affects machine design, marginalizing machine operators in production and minimizing the demand for highly skilled labor. He pointed out that the emergence of a "numerical control machine" has caused devastating damage to the skills mastered by machine operators.

Bright (1958:186–188) more specifically explained the relationship between mechanization and skill change. He divided the level of mechanization into seventeen levels, as follows: when mechanization is at level one to four, the tools are controlled by workers, and the skill levels of workers rise; when the mechanization reaches level five to seventeen, the machine has undergone the development process of mechanical device control, external signal control, and variable control, and the skill levels of workers continue to decline; when it reaches the seventeenth level, the highest level of control, the machine becomes a real automatic machine, and workers no longer need to spend much physical or mental energy on production activities and become zero-skilled "guards" or "monitors."

Supporters of the "upskilling thesis" believe that the abovementioned "deskilling" view applies only to individual labor processes and specific types of workers, and attention should be given to the impact of automation on most types of workers. They advocated that automation technology can create new skilled jobs and "reskill" the affected workers (reskilling). Among them, the views of Hirschhorn (1984) were strongly technically deterministic. He believed that technology itself determines various organizational forms, including the integration of work tasks, the use of skills, and the emergence of workgroups. Social relations are merely "behavioral manifestations" that depend on technology. Adler (1992), who held an interpretive perspective, believed that automation technology itself favors high-skilled jobs and that new skills replace the old ones, and even the machine operators affected in the Noble study case may become programmers through reskilling. However, in reality, this transformation is often difficult to achieve, and examples of Chinese blue-collar workers upgrading to programmers are rare.

Just as technology has a dual effect on employment, the impact of technological progress on worker skills is likely to be two-way; i.e., some types of workers are deskilled, while other types of workers have improved skills, or cases are even more complex. The re-division and combination of labor lead to individual jobs that include both deskilling aspects and skills-enhancing aspects (Hall 2010). One-sided judgments are not advisable. Therefore, in our research, we are more concerned about which workers are deskilled, how deskilling occurs and what results occur, which workers enjoy the opportunities and resources for reskilling, and what technology upgrading means for most low-skilled workers.

Technology and labor control

Labor process theorists believe that technology can strengthen or extend the control of workers' performance. One of the second-wave labor process theorists, Edwards (1979), proposed the concept of "technical control." He argued that although the technological application is not equivalent to technical control, mechanization itself is often accompanied by technical control because mechanization will cause workers to lose control over the pace of work and the workflow. He pointed out that the application of specific technology is the result of the manager's selection and the technology design, and this choice is based not only on cost and efficiency considerations but also on how to control labor better; that is, through technology, the labor purchased by the factory can be better converted into effective labor. The assembly line model of the Ford plant is the result of such a technological choice.

Although Edwards (1979) believed that streamlined "technical control" was gradually replaced by "bureaucratic control," later researchers such as Thompson (1989) discovered that the emergence of new technological forms has led to a more sophisticated and complex technical control strategy. This subtle technical control goes beyond simple machine pacing and is combined with increasingly complex bureaucratic control methods to standardize and coordinate the division of labor and task combinations in production. Thompson observed that this new type of technical control strategy is mainly based on modern information and communication technology. It results in the enhancement of the managerial control of "information." By mastering the information, it is possible to monitor workers' daily work, production efficiency, and compliance with production processes and rules and regulations. Managerial strategies no longer rely on traditional direct control. Information technology-based control strategies have effectively strengthened managers' control capabilities, expanded their scope of control, and internalized workers' self-discipline. Therefore, this control strategy has been compared to an "electronic panopticon" (Mckinlay and Taylor 1998; Sewell 1998).

Control also means resistance. Although this perspective on workers' subjectivity was ignored by Braverman, it was demonstrated in the second and third waves of labor process studies. In the second wave of labor process studies, theorists argue that although the use of technology is conducive to using capital to strengthen labor process control, workers are not passive receivers, and their subjectivity is embodied in the different choices of "resistance" and "consent." Resistance can be in the form of negotiations, strikes, or other violent protests against employers on labor conditions or in the form of daily, small-scale "improper behavior" (Ackroyd and Thompson 1999). "Consent" means that workers voluntarily participate in the factory's "making out" game (Burawoy 2008) or that workers can manage themselves and cooperate with teams under the premise that factory managers provide relative autonomy, such as Toyota's lean production model. In recent years, labor process scholars have tended to agree with the social construction of technology (SCOT) theory, that is, trying to break away from the Marxist argument about the "structural antagonism between labor and capital" and understand the action logic of capital, workers, and the state from the perspective of hermeneutics (Hall 2010). In the process of capital's continuous pursuit of production process changes, it is necessary to seek the cooperation of workers to a certain extent and enable them to exert their creativity, so as to understand different responses of workers-resistance, adaptation, obedience, and consent (Thompson and Vincent 2010). The above viewpoints show that the opposition between capital and workers is not static but interacts in the labor process and is affected by different factory regimes. It is a dynamic and diverse relationship.

In summary, the evolution of technology has both physical and social attributes. It not only reflects the dynamic power relationship between labor and capital in the production field, whether opposition or cooperation, but also reflects the social choices made by capital, workers, and even the state in a multiparty game. Specifically, what factors have affected the developmental path of technology? Western researchers point out that the choice and influence of technology depend not only on the technology itself but also on conditions other than technology, such as the market environment in which the enterprise is located, organizational factors, the role of trade unions, industrial relations, and labor market conditions. (Kelley 1986, 1990; Penn 1982). In the following discussion, the authors will also explore what factors influence and shape the technical choice of "robots replacing humans."

In this research, the authors draw on the analytical perspective of skills and labor control in labor process theory and believe that the labor relations' perspective must be added to understand the changes in the power relationship between labor and management more comprehensively. Therefore, this research adopts a two-dimension analytical framework. First, from the perspective of labor relations, we examine how employers can change the work content, labor conditions, and even the employment methods after mastering the initiative to reduce the workforce. Second, from the perspective of the labor process, we examine how employers can transfer labor skills and labor control by transforming the mode of production and management. It is worth pointing out that labor relations and labor processes are not parallel dimensions—the two interact and interlock with each other, forming the connotation of labor.

Case study: "Intelligent Manufacturing" on the shopfloor

The first author of this article conducted field research and interviews with nearly 20 companies in Guangdong Province in 2018, including companies that have implemented the process of "robots replacing humans," robot manufacturers, and robotics application training institutions. At the enterprise level, the interviewees that the author reached were mainly corporate management interviewees, including human resources department managers and technical department managers. These interviewees can provide a general introduction to the company's technology upgrading and labor conditions but fail to provide specific information on changes in the labor process in the workshop. Therefore, the author also searched for workers with relevant experience—most of which came from companies undergoing or had completed automation upgrades or trainees from training institutions who wish to cater to the trend of robotization through skill upgrading. At the same time, the authors also conducted participatory observation.

In August 2018, the two authors entered Factory B and Factory C, which were the cases used in this article, as general workers in the workshop. Using the factory floor as a field of observation, we observed and compared the production processes of manual and automated lines, as well as the labor processes of workers. By working with ordinary workers for an extended period, we were able to experience the labor intensity in the workshop, the managerial control methods, and the workers' cognition and attitude toward robotization.

Based on the above interview and observation data, this article selects three factories for the case analysis. The three cases selected are quite representative. First, the three factories belong to the following three industries: the auto parts industry, household appliance industry, and furniture industry. Different industries have different levels of progress in promoting automation. For example, Factory A, which belongs to the auto parts industry, successfully adopted automation before introducing relevant national policies, while for household appliances (factory B), furniture manufacturing (factory C), and other industries, automation was carried out following the industrial upgrading policy in recent years. Therefore, the three cases can reflect the different stages of robotization. Second, the three case factories belong to different types of capital and enterprises; Factory A is a Japanese-owned enterprise, a secondary supplier of an automobile manufacturer, and a medium-sized enterprise; Factory B is a private enterprise that does both independent R&D and OEM production and is a large-scale enterprise; Factory C is a Hong Kong-Taiwan joint venture, and its products are independently developed and produced. It is also a medium-sized enterprise.[1] Finally, the degrees of automation of the factories in the three cases range between semiautomation and high-level automation, which is in line with the status quo of most Chinese companies that have implemented automation upgrades; however, the three cases have certain differences in terms of the penetration rates of robots and the methods of automation. These differences also have different effects on the labor process and working relations in the workshop. The specific conditions of the three cases will be introduced below.

Factory A

Factory overview

Factory A is located in the automobile industrial park of the famous Japanese automobile manufacturer S in Guangzhou. It was established in 2004 and belongs to a wholly Japanese-owned automobile seat manufacturer. Its products are automobile seat frames. Thanks to Japan's advanced robotics technology, Factory A has already started automation upgrades and robotization for its production line transformation. According to some veteran workers, the factory purchased industrial robots and used them for welding seat frame components at the beginning of the establishment of the factory in 2004, but they were only used on a small scale at the time. In 2012, Factory A successfully transformed approximately 20 production lines for the seat frames of five car brands. Today, nearly 90% of the production lines in Factory A have upgraded the production to

[1] The classification of enterprise types is subject to the "Measures for Classification of Large, Medium, Small and Micro Enterprises (2017)" issued by the National Bureau of Statistics.

"mainly welding robots, supplemented by a small amount of manual welding, and then supplemented by the manual assembly and loading and unloading."

Changes in the labor process

The products of Factory A are car seat frames. Its main production process involves assembling and welding various seat frame parts, and welding is the core production process. Before robotization, there were approximately 300 welders in the factory; now, there are only dozens of welders engaged in manual welding in the factory, and they are distributed on a few manual welding production lines or automated production lines engaged in welding the small parts left by a few robots.

We take the front seatback frame of a certain model as an example to illustrate the production process of this specific product and the changes in the labor process of workers before and after the introduction of robots. The production of this seat back frame consists of the following nine processes: (1) sidearm welding; (2) angle adjuster welding; (3) handle welding; (4) headrest welding; (5) assembly welding; (6) connecting rod welding; (7) spring net assembly; (8) precision inspection; and (9) quality inspection. Before the introduction of robots, these nine procedures were all completed manually. The first six procedures are completed by welders, who need to assemble the parts, weld the corresponding parts, and then put them on the transmission line and pass them to the next station; the last three inspection procedures are usually completed by general workers. Each manual welding production line needs approximately ten workers.

Following the introduction of robots, the production process itself has not changed much, and only some procedures and operations have been "transferred" to robots, but the content of the work performed by workers has undergone major changes. Workers who were originally engaged in assembly and welding now only need to put the corresponding workpiece on the corresponding workbench of the robot and perform simple assembly operations (such as installing small parts, installing steel wires, and installing springs) and fix them with clamps. The robot completes the welding operation according to the set path. When the robot is working, the worker not only needs to monitor the machine, but also has his own work to do. Since a robot usually corresponds to two workstations, the worker needs to go to the adjacent workstation to complete the preparation work of taking out the welded workpiece, transferring it to the next workstation, and repeating the above assembly work.

It can be observed from the above labor process that the skilled workers who originally engaged in welding degenerated into general workers who perform auxiliary tasks for robots. According to an interviewed worker, these auxiliary tasks "do not require special training, no technical workers needed, general workers are fine. Workers just need to be taught how to assemble parts in the early stage of the job, and now they are still recruiting interns from vocational schools to work… There is no need for workers to operate robots, and there are special maintenance personnel when there is a problem" (Interview Record A-XXX).

The use of robots has not made the job of workers easier. As a Japanese company, Factory A also pursues Toyota's Lean Production. The management accurately calculates the time required for each process and even each operation in seconds. An interviewed worker used his operation as an example to introduce this lean production method. If the robot welding time for a certain part is set to 60 s, the three steps of spring installation, precision inspection, and patching are required, which each takes 20 s to complete. The former requires the same time as the last three steps. The robot assistant's job is to remove the workpiece within 60 s and complete the subsequent three steps of spring installation, precision inspection, and patching. (Interview Record A-ZWX). So-called lean production is embodied here as not wasting a second and not producing any redundant actions.

Following the introduction of robots, this lean production method was more thoroughly implemented. In the manual welding stage, although managers also emphasize production efficiency and reduce wasted time, these are usually regulated by the overall daily output, and it is impossible to control each operation that the workers perform precisely. Workers have to assemble and weld. Some operations are fast, and some are slow. Workers can also coordinate and cooperate with each other. However, after introducing robots, the production speed cannot be "artificially" interfered with by workers because the robot speed is fixed, and people must keep up with the rhythm of the robot. A veteran worker working in Factory A for more than ten years said, "The job now is twice as tiring as before. Because the output is higher and the pace of work is faster, people have to follow the robots. Machines have quickened the pace and men have to keep up with them. In the past, it was manual welding. People could do it faster or slower, and it didn't matter if you did it slower. Now everyone complains (after robotization) that we will live on air" (Interview Record A-ZQH).

Changes in working conditions and employment methods

Due to the overall increase in car sales in recent years and the establishment of an internal collective bargaining mechanism by auto parts companies after Honda's strike in 2010, Factory A, as a manufacturer of auto parts, has a higher level of wages and working conditions compared to others in the manufacturing industry. Workers entering the factory are usually dispatched workers with a basic salary not lower than the local minimum wage standard and enjoy a year-end bonus equivalent to five months' salary. Workers will have a certain percentage of salary increase every year after they are converted to regular workers, and they can apply for rank promotions based on their work performance. Taking a regular worker (general job post) with eight years of service as an example, his monthly salary is approximately 4500 yuan; when adding the provident fund and year-end bonus, his average monthly income can reach 8,000 yuan (Interview Record A-ZWX).

Welders, as the workers most affected by the robotization process due to their skill requirements and exposure to harmful substances, such as dust in the working environment, are entitled to a monthly skill allowance and environmental allowance of 350 yuan, which are included in the fixed salary as the calculation base for overtime pay and the year-end bonus. After the introduction of welding robots, a large number of welders were forced to become general workers. The management once issued a notice to cancel the allowances that welders originally enjoyed on the grounds that welders did not need to engage in welding operations. This reduction in benefits was met with protests from welders. The welders in a certain production line expressed dissatisfaction through the suspension of work, but then the entire line of workers was fired; additionally, most other welders refused to sign the company's resolution and constantly asked the union to negotiate and communicate with the management. Finally, after a year of coordination by the labor union, both parties reached a resolution—the allowance for welders no longer engaging in welding operations was reduced to 120 yuan per month, and the remuneration of welders still engaged in welding operations remained unchanged.

After the successful transformation of the factory's production line, the number of workers gradually decreased. Before 2012, the total number of employees in the factory was more than 1000. In 2018, the total number of employees was reduced to more than 700, decreasing approximately one-third. Unlike the other two case factories in this article, Factory A provides a better salary and has a lower natural employee turnover. Therefore, the method of layoffs adopted by management is their so-called rationalized reduction of staff plan, that is, by negotiating financial compensation with employees for their resignation. Employees who leave after the negotiation can receive at least an economic compensation equivalent to "N + 1" of their monthly salary.

However, layoffs and the decline in the remuneration of some workers are only the most direct negative consequences of robotization. The replacement of core processes by robots means that the demand for skilled workers in factories is reduced, and most of the needs are for low-skilled auxiliary workers. This change means that the high-wage and high-benefit salary system adopted by management to maintain a stable, skilled workforce in the past has been challenged. Since ordinary workers can perform auxiliary tasks after simple training, the factory does not need to continue to pay high wages to keep these experienced and skilled workers. Therefore, the employment method of Factory A has also changed in the past few years; in the past, workers generally entered the factory as dispatch workers, and after one year, when they passed the assessment, they could be transferred to regular workers. However, it takes two to three years for dispatch workers to become regular workers in recent years. At the same time, the factory also added two types of employment, i.e., student workers and temporary workers. During the peak production period, the factory recruited many students for internships through cooperation with vocational schools and recruited temporary workers through labor service companies. The wages of these two types of workers were only 13 yuan per hour (equivalent to the local minimum wage standard), and they do not enjoy other benefits; thus, the compensation paid to these workers is far lower than the labor cost of hiring regular workers. These two types of workers not only meet the flexible employment needs of enterprises but also save enterprises' labor costs.

Factory B

Factory overview

Factory B is a large-scale air-conditioning manufacturer, which is now part of a famous national household appliance enterprise Group T. As a large enterprise with a market value of nearly RMB 400 billion, Group T has spared no effort in investing in promoting technological transformation. Since 2011, it has carried out a "three-step" intelligent transformation of household air-conditioning production: automation, informationalization, and intelligentization. Different from the technological transformation of ordinary enterprises aiming to "reduce workforce and improve efficiency," Group T's technology upgrading aims to build an "intelligent system" that includes production, logistics, and sales. In addition to introducing robots and building smart factories, it is also necessary to use big data analysis and open up the production chain to make all businesses interconnected. Factory B, which has spent hundreds of millions of yuan on technological upgrades, has become an intelligent manufacturing demonstration base widely publicized by the media and a benchmark for the industrial Internet.

In terms of automated production, Factory B currently has 20 indoor unit and outdoor unit assembly lines. Two automated production lines (one for indoor units and one for outdoor units) were launched in 2015, but the remaining 18 production lines still relied on manual assembly. The automated production line currently achieves a 65% automation rate. Each production line has more than 40 robots, but 20–30 workers are still needed to perform the auxiliary tasks that the robots cannot complete. The number of workers has been reduced by more than half.

Changes in the labor process

The production of the indoor and outdoor air conditioner units mainly includes assembling various parts and welding a small number of parts. Take the production line of the outdoor air-conditioner unit as an example. The line contains approximately 30 processes, such as placing foam boxes and metal base plates, labeling, placing compressors, fixing compressors, unplugging foot plugs, welding condensers, assembling condensers, installing high- and low-pressure valves, and adding nitrogen. The most numerous positions in a production line are assembly positions, and the workers engaged in assembly positions are general workers, that is, workers who can perform the job without mastering special skills.

The production of the outdoor air-conditioner units is almost the same on the automated and manual lines. The difference is that more than half of the processes on the automated production line are completed by robots. Taking the automated line of an outdoor air-conditioner unit as an example, among the 30 production procedures, machines or robots performed 20 procedures, and workers completed the remaining ten procedures. Although they are on the same production line, the workers' jobs and robots' jobs are separated. Most workers' jobs are auxiliary tasks for loading and unloading materials, and some jobs require high flexibility but do not have skill requirements, such as wiring and wrapping sound insulation cotton and fixing coils. Except for a small number of welders, halogen leakage inspectors, and versatile workers, most positions have low skill requirements. A line leader who has worked for many years said, "working in the automated line is the same as the manual line outside. The equipment is to be repaired by specialists. We do not need to understand, but just need to pay attention to our safety" (Interview Record B-SC). After robotization, the skill requirements of frontline workers have not been upgraded.

In terms of production management, both automated and manual production lines are Taylorist assembly lines, which seem to be the same. However, in actual production, each process on the manual line has a button that workers can press to pause to handle a situation in which production cannot be continued. At the same time, the workers of each position are very close to each other and can know each other's production situation. They can help each other and adjust the production speed. When the author worked as a novice, workers at the neighboring post often "lend a hand" to help complete the task. While automated production lines and robots jointly control the production speed, most front-line workers are scattered between machines. They need to adapt to the high-speed machine production rhythm, and it is difficult to obtain help from other workers.

Changes in working conditions and employment methods

Since robotization has not yet been fully implemented in Factory B, we were able to compare the differences in labor conditions between automated production lines and manual production lines in the same period. Before entering Factory B for participatory observation, the author had the opportunity to formally visit the factory and interview the management personnel. Although managers claimed that workers in automated production lines have to meet higher requirements in terms of academic qualifications and skill training and that their terms of employment are better than those in manual lines (Interview Record B-M1), this claim is quite different from the findings of the author's field investigation. In fact, the automation upgrade of the factory does not require higher education and skills for front-line workers, nor does it bring significant changes to the terms of employment. First, newly recruited workers are randomly assigned to each production line according to the labor demand of each department. The personnel staff stated that regardless of the type of production line, the requirements for general workers are uniform. Second, after the author came into contact with the workers on the automated production line, they found that among them were middle-aged general workers who had been working for less than three months, as well as summer student workers who had not graduated. They are no different from workers on the manual production line regarding academic qualifications, skills, recruitment, and orientation training. Finally, regarding employment, the salary calculation method for the automated line and the manual line is the same, which consists of the following three parts: basic salary, overtime pay, and job allowance. The basic salary is the local minimum wage standard, and the job allowances are slightly different depending on the job operating skills and the operating difficulty coefficient. Since the work content and the education and skills of the workers in the automated line are not significantly different from those of the workers in the manual line, their wages are far less than the declared wage by the managers; if there are limited overtime hours, their income may not be as good as that of manual line workers. It can be seen that the so-called labor upgrading in Factory B did not happen to the production workers of the automated line.

In terms of the total number and methods of employment, although Group T, to which Factory B affiliates, has publicized through media the significant reduction in the number of workers needed for household air conditioning through robotization, the reality is that Factory B has been in a state of labor shortage and constant recruitment in recent years. Factory B uses the local minimum wage as the basic salary, with long overtime hours and high labor intensity; therefore, the employee turnover rate has been high, with a monthly natural turnover rate of 10–20%. A large slogan was hung in a conspicuous place in the factory area, claiming that an "internal recommendation of general workers will be rewarded with one thousand yuan, without an upper limit." When age restrictions are relaxed and academic qualifications are not required, the factory still needs to establish an incentive mechanism to encourage employees to introduce relatives and friends to apply for jobs in their factory. In addition to the abovementioned methods, Factory B began to cooperate with some schools to recruit summer workers to compensate for labor shortages during the peak summer production period. The discrepancy between the publicity of Factory B and the actual employment situation reflects the hidden tension between the input cost and return, the projected image, and the actual utility that the enterprise faces in the process of promoting intelligent manufacturing and "robots replacing humans."

Factory C

Factory overview

Factory C is affiliated with a Hong Kong-Taiwan joint venture and was established in Guangzhou in 2000; the company's main product is office furniture. Its office computer chairs are among the top sales of similar products on an e-commerce platform. With the increase in sales volume, recruitment became increasingly difficult. Factory C began to introduce automated production in 2017 and successively purchased more than 20 robots. These robots are used for component assembly, cushion covering, and finished product packaging and handling processes and are distributed within the two main production workshops of the factory. Among them, ten robots engaged in assembly and covering processes are distributed within an independent automated production area; several robots with the same function are scattered around the manual production line; two sets of automatic packaging and handling robots are located at the shipping port in two production departments. In general, Factory C has been practicing semiautomated production of manually assisted robots on a small scale.

Changes in the labor process

The factory focuses on high-end office computer chairs with "ergonomic" designs and market prices ranging from one thousand to nearly 10,000 yuan. In fact, the production process and technology do not have very high technical content. A computer chair is mainly composed of cushions (optional headrest), seat cushions, armrests, and chair legs. The production line is also classified according to the main components and processes, such as seat cushion group, assembly group, and packaging group. To put it simply, the production process of a computer chair mainly includes the following steps: covering process (cover and fix the fabric on the cushion or cushion frame), assembly process (assemble the inner and outer frame, cushion, back cushion, and other parts with screws), and finally quality inspection, disassembly, and packaging.

Instead of automating and upgrading the production line as a whole as at Factory A and Factory B, the use of robots in Factory C is primarily reflected in the assignment of partial processes to robots for completion rather than transforming existing production lines. The robots currently introduced are mainly responsible for the three processes of cushion covering, assembly, packaging, and handling. Take the cushion covering of a certain model of computer chair as an example. The manual covering process first requires covering and wrapping the fabric on the outer frame of the cushion, then nailing and fixing the outer frame with a special nailer, and finally, cutting off the excess fabric with scissors. It takes more than one minute for workers to complete a workpiece, and they need to have a certain degree of proficiency and considerable operating skills to be competent. If an automated covering robot is used, the robot's work cycle is approximately 60 s per workpiece. One robot can produce at two or four stations, and at least one worker must assemble parts. This worker's job is to place the cushion on the mold of the first station, place the fabric on it and fix it with a clamp. This is the preparation for assembly, and then the robot arm moves to the station, according to its set track, to complete the task of nailing. During the 60 s in which the robot is engaged in nailing, the worker moves to the second station, removes the processed workpiece, and repeats the assembly preparation work. This cycle of cooperating with the robot to work on two workstations alternately is repeated.

It can be observed from the above labor process that the demand for skilled workers in the automation department is not high, and most of the manual work is auxiliary work, such as loading, unloading, and assembly. Compared with the skilled workers on the manual line (such as workers engaged in covering and inspection), the demand for skilled workers in the automation department is reduced; however, compared with most general workers (such as screwing) on manual lines, the skill requirements are not much different.

In terms of the production rhythm, robot assistants cannot control the rhythm autonomously. They must keep up with the speed of the robots. On a packaging line composed of workers and handling robots, the robots located in the later process will bring visible pressure to the workers in the previous process, and the workers have to speed up the pace of work to prevent the robot from stopping for too long. In contrast, in the manual line, the rhythm of the assembly line has a certain degree of flexibility and does not overemphasize the time spent in each process. Workpieces that are temporarily too late to be processed on the assembly line can be temporarily placed in the corresponding storage area of each station, and workers at the front and rear stations will also help each other when needed. Therefore, the pace of work on the manual line is relatively more elastic. The accelerated production pace on the packaging line caused dissatisfaction among some old workers when the robot was first introduced. They tried to deliberately destroy the carton to make its appearance irregular, causing the robot to fail to recognize the package and activate its protective device to stop operation. Later, the management reprimanded the old workers and eventually replaced them with new workers; after that, sabotage seldom occurred (Interview Log C-LJQ).

Changes in working conditions and employment methods

Although the automation department does not have high requirements for the actual labor skills of robot operators, management still highlights the advantages of the department in terms of employment remuneration, such as giving workers a monthly technical allowance of hundreds of yuan, providing internal training, and issuing a "robot operation certificate." However, not all workers who work with robots receive this treatment. Those packaging and handling workers on the packaging line, as well as workers who are responsible for trimming and placing the leftovers at the back end of the robot, do not need to touch the machine for their work; thus, there was no improvement in treatment, and no additional training was required.

In terms of employment, the factory is researching and promoting "full production automation" on the one hand, and on the other hand, it is solving the current shortage

Table 1 Changes in the connotation of labor after technology upgrading

Investigation dimension		Factory A	Factory B	FactoryC
Labor relations	Labor cut	Approximately one third	Nearly a hundred people	A small amount
	Working conditions	Wage reduction; intensity increase	Wages are flat or reduced; equal intensity	A few workers' wages will increase, while the rest will remain flat; intensity may increase
	Employment methods	Dispatch workers, student workers, temporary workers	Dispatch workers, summer jobs	Summer jobs, temporary workers
Labor process	Skill changes	Deskilled core work	Some posts remain unchanged, while some skill posts are replaced	Partly rises; some remain unchanged
	Labor control-resistance	Strong technical control; actively defending interests	Strong technical control; no resistance observed	Strong technical control; passive resistance

of labor through multiple channels. A "Feasibility Analysis Report on the Production of Comprehensive Automation Projects" disclosed by technicians of Factory C shows that the proportions of productivity by covering robots or assembly robots in the automation department (the number of robots corresponding to each model product is usually one or two) are all higher than 50% and reach up to 86%. The report's analysis pointed out that continuous debugging and optimization of machine performance and production management improvement can further improve the production efficiency of robots. At the same time, management is also considering extending the working hours of robots and even adding night shifts to increase the overall production capacity.

Although more than a dozen robots have been introduced, the problem of lack of labor in Factory C still exists. Due to low wages and high labor intensity, newly recruited workers often leave after a few days of trial work. In 2018, the factory added two recruitment channels: one cooperates with a township middle school, recruiting more than 100 fresh graduates to work summer jobs in the factory; the other cooperates with labor agencies, which assist the factory in recruiting temporary workers. Due to the persistent shortage of labor and the increasing number of orders in recent years, the automation process has not yet triggered layoffs in Factory C, and robots have replaced only a small number of porters. However, with the "all-around advancement" of automation, the unemployment risks faced by workers are increasing. In particular, hundreds of older female workers have worked for a long time and settled locally. They are worried about whether they will be able to continue to keep their jobs in the future.

Technology upgrading, labor degrading?

The above case materials describe and analyze the types of "intelligent manufacturing" that occur in the workshop from the aspects of the factory's robotization, labor process, labor conditions, and changes in employment methods. We summarize them in Table 1 and discuss them one by one below. It is worth noting that although the three cases are representative in terms of industry and capital types, the motivations, processes, and results of the robotization presented are not the same. However, what this part presents is not only the comparative significance and differences between the cases but also an attempt to find common ground behind these differences, that is, the common influence of robotization on the connotation of labor.

Convergence of labor conditions and flexibility of labor relations

Undoubtedly, machines are replacing workers, which is also the original motivation for most enterprises to automate their production. Due to the different penetration levels of robots in the three case factories selected in this article, there are still differences in reducing the labor force, ranging from a small reduction to a one-third reduction. Since the three case factories are still in the semiautomated stage, the labor replacement effect presented is not yet deterrent. However, with the popularity of robot applications and the continuous improvement of automation, the scope of work and the number of laborers that machines can replace will continue to expand.

Robotization also caused changes in working conditions, including the work content, wages, and labor intensity. However, these changes are different among different enterprises, and even within the same enterprise, there may be large differences for different positions (such as Factory C). On the surface, this difference depends on the company's overall salary level and the skill requirements of specific positions. We have found that robotization has caused the convergence of labor conditions in different industries and positions with different skills. For example, a large number of workers in Factory A have had their wages reduced because welders have been downgraded to general workers (actually robot assistants), while a small number of workers in Factory C have been "upgraded" from general workers to robot assistants, receiving lower wages than general workers in Factory A, because Factory A belongs to the auto parts industry, whose overall wage level is higher. It can be observed that robotization has narrowed the gap of wages and skill requirements of the two factories and even assimilated the production methods of two different types of products, making the labor conditions of these two factories converge. In the same way, as far as labor intensity is concerned, machines will first replace some heavy physical and high-risk labor because these jobs require higher labor compensation and skills. From this point of view, workers' jobs have become simpler and easier, but salaries and skills have also declined. On the other hand, the joint speed control of the machine and the assembly line may speed up the pace of the work. Although a single operation is easy, worker fatigue may not be reduced. With the increasing popularity of robot applications, the convergence of front-line workers' remuneration, labor intensity, and production methods should be an overall trend.

Due to the convergence of labor conditions caused by robotization, the scope of replaceable work continues to expand, and its consequences for labor relations have become increasingly unstable and flexible. It can be observed from the cases that various employment types, such as dispatch workers, student workers, summer workers, and temporary workers, are constantly emerging in addition to formal contract workers. This reveals that the "robots replacing humans" scheme has not yet solved the labor shortage dilemma during the peak production period of enterprises and has led to the popularization of short-term and flexible employment practices. Under the trend of technology upgrading, enterprises' reliance on a stable labor force continues to decrease, machines become the center of production, and workers are increasingly reduced to auxiliary and marginal labor.

Skills change: from "separation of concept" to "execution substitution"

Following robotization, the impacts on worker skills for the three cases were slightly different. In Factory A, welders and core workers are deskilled; in Factory B, the positions replaced by robots include both zero-skilled and low-skilled positions. In contrast, in Factory C, the skills of robot operators in the automation department appear ascended but actually descended. On the surface, workers need to undergo short-term training and enjoy certain skills allowances, but in fact, their job is just to assist the robot; and other workers who indirectly interact with robots, such as the workers in the automation department who are responsible for cutting fabrics and scraps, and the packaging workers on the packaging line, have no signs of skill improvement.

Based on the three cases, we believe that "deskilling" is still the main trend faced by front-line workers in the production workshop. However, in this round of technology upgrading, front-line production workers are faced not only with the separation of conception and execution but also with the degradation of skills caused by "execution substitution." Due to the introduction of robots, the content of execution is further refined and classified, part of the manual operations that include skills are replaced, and the remaining content for workers to execute has almost no skill requirements at all. In some highly automated production scenarios, the degree to which workers have been "execution-substituted" by robots is even worse; the execution content from loading and unloading to production and processing is completely replaced by robots and equipment, and front-line workers only need to take up the job of a "supervising crew" to ensure that the production line does not stall. They are no longer even called "production workers."

"Execution substitution" as a feature of the new round of "deskilling" is not only a possibility given by technology upgrading but is also a result of capital selection. First, the technology upgrading brought about by scientific and technological progress has created the possibility of "execution substitution." In the previous Taylor-Ford production model, the division of labor is to separate the "conception" from the labor process of the workers, but many "executions" still contain certain skill requirements (such as welding, polishing, spraying, turning and milling, and other common operation skills). In the era of robot manufacturing, after workers lost control of "conception," they gradually lost control of "execution." This is because robot technology and information technology have developed rapidly in recent decades, and the controllability, flexibility, and precision of robots have been greatly improved; thus, they can replace workers in performing simple and repetitive manual tasks (such as assembly, labeling, loading, and unloading) and are able to engage in tasks with both technical difficulty and high flexibility (such as welding, polishing, and spraying). With the application of new digital technologies such as tactile perception, image recognition, natural speech processing, and deep cognitive learning in the field of robotics, the ability of machines to substitute for human labor will increase.

Second, the new round of "deskilling" is not only the result of technological progress but is also a "social choice" dominated by capital. On the one hand, to reduce labor costs, capital will prioritize replacing skilled labor with higher per capita wages. In recent years, robots have been mostly used in polishing, grinding, welding, and other tasks. Because these jobs require high skills and easily cause occupational injuries, the per capita labor cost is quite high. On the other hand, in the eyes of employers, skilled workers are also difficult to manage. Due to their strong bargaining power, when they are dissatisfied with management, they are often more inclined to express and act than ordinary workers, greatly impacting the production order. In the three cases in this article, only the welders of Factory A dared to express dissatisfaction and even protested by suspension of work when they learned of the robotization scheme. An interviewed business owner said that because skilled workers in core positions are too important for production operations, once individual employees are upset or leave, it may delay the operation of the entire production line. Therefore, their company is beginning to develop a new set of solutions, as follows: "We are now collecting key information for each core station, what problems exist, and how to solve them, one by one. Even if the freshest hands come over, they can quickly find the solution… We will make this thing into a manual, so that experience becomes less and less important, and operation becomes more and more important" (Interview Record SK-DGQ). It can be observed that the employer's consideration of both labor cost and managerial risk has prompted it to make a "deskilling" technology choice.

Of course, we also need to realize that the "deskilling" encountered by front-line production workers (blue-collar workers) is not the whole story of the robotization phenomenon, nor can it represent the experiences of all manufacturing workers. In theory, production technology innovation means that workers with higher skills and knowledge must be matched, which means that other workers can take advantage of this trend to obtain opportunities for skill improvement. Robot engineers, automation engineers, and machine equipment operation and maintenance personnel are undoubtedly the beneficiaries of this wave. Therefore, on the whole, the technically upgraded manufacturing industry's demand for workers' skills is reflected in "skill polarization," and the "deskilling" of front-line production workers corresponds to the "upskilling" of technical personnel. The emergence of skill polarization does not reflect changes in the absolute level of skills but changes in the "relative share" of skills and knowledge mastered by specific groups (Vallas 1990).

It is foreseeable that the application of robots and other new technologies will increasingly replace the labor of workers; that is, the degree of "execution substitution" will continue to increase, and the result will not only be "deskilling" but also the disappearance of low- and middle-skilled jobs. Although there will be a talent gap of millions of skilled jobs in the next ten years, the drastic changes in the labor structure caused by the polarization of skills will not be neglectable. A large number of low- and medium-skilled laborers need to be smoothly transitioned and transferred. The transition still needs to be further integrated and perfected in China's social security, skill formation, and retraining systems.

Labor control and resistance: strong control-weak resistance

In the three cases in this article, labor control since robotization has been strengthened. The production scenarios of these three factories explain how labor control based on automation and digital technology occurs, which can be embodied in three aspects. First, the emergence of robots and other automated equipment has strengthened the previous assembly line technical control, that is, controlling the work pace. Before the automation upgrading, the manager's control of the production process was mainly reflected in the design of the assembly line to split the production process into multiple procedures and assign work tasks to each position while controlling the speed of the assembly line. This is what Edwards calls technical control (Edwards 1979). This Taylorist assembly line still has a certain degree of flexibility; that is, on the premise of completing the task of the day's output, workers can adjust the pace of production to a certain extent, such as speeding up when they are motivated and slackening when they are tired. The line chargeman will also increase or decrease the number of workers according to the output. Following the automation transformation process, robots became the center of the entire production process. Robots control work pace, calculated in seconds. Therefore, the flexibility of manual assembly work is completely lost. The change in the division of labor and the reduction in the number of workers has also eliminated the possibility of workers helping and cooperating with each other.

Second, the integration of digital technology and production processes has weakened the role of grassroots managers as "direct control" but strengthened the control method of managers based on digital technology. Managers outside the production workshop can use digital and visual methods to instantly monitor the production and worker performance. The manufacturing execution system (MES) in Factory B is a typical embodiment of this type of digital control. Through this type of MES management system, the production data of all equipment are uploaded in real time. Every segment of the production line has an electronic screen that displays the production speed, progress, material supply, product qualification rate, and equipment failure; these data are transmitted to the system backend at the same time so that the managers and equipment operation and maintenance personnel outside the workshop can be informed in a timely manner of the production situation; coupled with the ubiquitous surveillance cameras, a set of digital labor control systems with the functions of real-time monitoring, rapid response, and low management cost is formed.

Finally, robotization indirectly strengthened "bureaucratic control" by "deskilling." Friedman (1977) pointed out that capitalists can adopt a divide-and-conquer approach to deal with core and marginal workers, which is bureaucratic control. However, the result of robotization is not only to divide and conquer workers but also to transform some core workers into marginal workers. Because robots greatly weaken the dependence on core workers with skills, management can use general workers, dispatch workers, temporary workers, and summer job-takers to replace them. The stratification inside the labor force is significant, and the terms of employment enjoyed by different types of workers are different. This process of transforming core workers into marginal workers weakens workers' bargaining power in the workplace and puts them in a more fragile labor relationship. From this perspective, technical control can be integrated with bureaucratic control.

The above changes also make workers' resistance of little significance in a robot-centric mode of production. At present, the workers' resistance behaviors we have learned about are mainly for the defense of their own interests or are either active or negative reactions; for example, the welders in Factory A protested for the retention of skill allowances, and part of the allowances was reserved through negotiation between the enterprise labor union and the management; a few old workers in Factory C destroyed the product package, making the machine unable to identify the package and temporarily paralyzing the production line. However, these resistance behaviors were easily resolved by management. The workers were dismissed, compensated, persuaded, or transferred. Regardless of whether workers realize that the arrival of robots is the root cause of the damage to their interests, they have no opportunity to participate in the decision-making and execution process of the factory to promote the "robots replacing humans" scheme and automation upgrades. Many workers in the three factories said that the companies did not consult any workers or even notify them of automation upgrades. This also means that they can only react passively to the plans implemented by the management, and this response further prompts the management to accelerate the transformation of the machine-centric mode of production.

The formation mechanism of robotization

Based on the above analysis, regardless of whether it is the transformation of labor relations or the changes in worker skills and labor control during the labor process, we can infer that, in the context of technology upgrading, production workers have encountered varying degrees of "labor degrading." Compared with Braverman's "labor degradation," the "labor degradation" brought about by robotization has been extended in three aspects. First, robots are able to carry out "execution substitution" for a large number of manual tasks through a further refined division of labor, which intensifies the degree of deskilling of front-line workers. On the other hand, digital technology is used to adjust the control strategy of the labor process and is combined with bureaucratic control so that workers' control over the labor process is further transferred. At the same time, the labor relations workers face have become more fragile; the number of low-skilled jobs has decreased, salary increases are difficult to obtain, employment methods have become increasingly unstable and flexible, and workers lack the opportunities and human capital for reskilling.

To determine the formation mechanism of such a technology selection, we need to go back to the source of robotization and examine the economic and social environment and institutional conditions of China's manufacturing industry. The following section summarizes the boosting factors and limiting factors.[2]

From the perspective of boosting factors, competition in the global capital market has become increasingly fierce in the past ten years, and the disappearance of China's demographic dividend advantage altogether means that the "world factory" model that relied on cheap labor in the past is facing an inflection point. The "robots replacing humans" scheme with the goal of "cutting staff and increasing efficiency" is the technology choice most companies use to deal with the abovementioned development bottlenecks. In this context, the state has issued a series of industrial upgrading and transformation policies guided by "Made in China 2025," focusing on the development of high-end

[2] Due to space limitations, this article only provides a general analysis. For a more detailed discussion on the background and formation mechanism of "robots replacing humans", please refer to Xu and Xu (2019).

manufacturing industries and gradually eliminating labor-intensive low-end industries, supplemented by a large number of supporting policies and scientific research, fiscal and taxation, and financial measures. In the specific technical design, the previous discussion regarding the skills and control methods of the labor process has also reflected the leading role of corporate capital. It can be observed that the capital, the state, and the labor market constitute the boosting factors of robotization with the goal of "reducing the workforce and increasing efficiency."

On the other hand, robotization can cause a large degree of "labor degradation" because of its lack of restrictive factors. As Western scholars have pointed out, the impact of technological progress on workers also depends on conditions such as trade unions, industrial relations, social policies, and labor market conditions (Kelley 1986, 1990; Penn 1982), which can affect the direction of technology choice to a certain extent. However, during the author's investigation, few restrictive factors affecting the robotization decision-making process were observed. First, the role of trade unions in the technology upgrading of enterprises is not obvious. In the three cases in this article, only the labor union in Factory A played a role in helping workers fight for their rights, while the role of the labor unions in the other two factories did not appear. In other companies surveyed by the author, few trade unions play a role in enterprise automation upgrades. Second, governments' human resources and social security departments at all levels should have paid attention to the negative impact of technology upgrading on workers. However, the focus of these government departments is whether robotization can effectively solve the problem of labor shortages or rising labor costs for local enterprises. As long as there are no large-scale collective disputes, the administration departments of human resources and social security hold a welcome attitude toward robotization, and some local governments are even proud of the remarkable effect of robotization in reducing labor.[3] In addition, workers themselves are still insufficiently aware of the risks of robotization, and it is difficult to express collective appeals in an organized way and influence enterprises' technological transformation decisions. The wave of robotization in recent years has not met with large-scale resistance from workers, which is also related to this factor. Although many companies continue to reduce labor due to the high mobility of workers and the high turnover rate, companies only need to wait for the natural loss of workers without paying the corresponding price for large-scale layoffs.

Overall, in the manufacturing industry's technology upgrading process in the Pearl River Delta, the capital, the state, and the labor market have played key promoting roles and have formed an enterprise-led, machine-centered approach to robotization without workers' participation. Figure 1 shows the formation mechanism of robotization and its influence on labor connotations.

In fact, technology upgrading, such as automation and intelligentization, is an irreversible historical trend, but technology upgrading does not necessarily bring about labor degradation. In recent years, China has promoted the "craftsmanship" of the new era, which means that the importance of manufacturing talent has received a certain

[3] The first author of this article participated in several tripartite forums held by the Human Resources and Social Security Bureau, trade unions and enterprises in Dongguan, Foshan, Huizhou, Shaoguan and other cities in Guangdong Province from November 2018 to September 2019 and made judgments based on this.

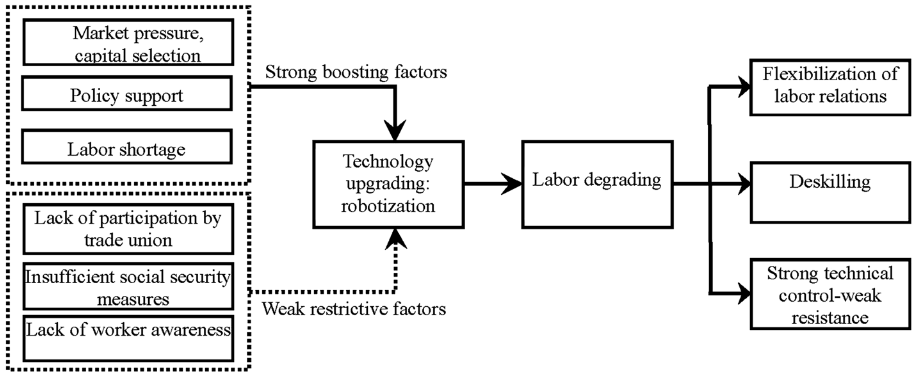

Fig. 1 The formation mechanism of robotization

amount of attention. However, it is not enough to just promote "craftsmanship." How to construct a human-centered "craftsman system" is the key. Germany, which put forward the concept of "Industry 4.0," while promoting technology upgrading, also emphasizes the balanced relationship between technology and people and promotes work upgrading. Its experience is worth studying. One lesson is that social dialog and consultation should be emphasized. Because German companies attach great importance to multiple parties participating in social dialog with worker representative mechanisms such as trade unions, trade unions often conduct surveys for this, discuss the impact of digital trends on work, and participate in decision-making regarding the upgrading and transformation of enterprises. The second lesson is to attach importance to lifelong training and education for workers. The German government, enterprises, and trade unions all emphasize life-long innovative education for workers and are willing to bear the time and economic costs of workers' education to remain competitive in a new mode of production. Third, blue-collar workers can gain sufficient social respect. Blue-collar workers are regarded as the backbone of the German industry, and their wages and social status are no less than those of white-collar workers so that German manufacturing can attract sufficient talent.[4] Based on the above points, Germany's automation upgrade has formed a worker-centered participation model. The labor force comprises highly skilled and autonomous mechanics with extremely high overall skill levels, which has further become a powerful driving force for Germany to develop advanced manufacturing.

Conclusion

Some scholars have pointed out that China's macro policy on manufacturing is aimed at comprehensive industrial upgrading driven by value chain upgrading (Lüthje 2019). However, in catching up with international standards and advanced manufacturing, both positive and negative effects brought about by technology upgrading are occurring. It is foreseeable that, as a populous country, a large number of low-skilled jobs

[4] Germany's experience in promoting "Work 4.0" is based on the author's summary based on the reports of many German experts at the "Intelligent Manufacturing and Work 4.0 Seminar" in 2018, including Uwe Stoffregen, the Director of the Social Affairs Department of the German Embassy in China, Moritz Niehaus, a German metal industry trade union representative, Florian Butollo, a Weizenberg Berlin Social Science Center researcher, and other reports, in addition to Botthof and Ernst (2015).

are being or will soon be replaced, and large-scale structural unemployment may still occur, but this risk is being concealed by the "labor shortage and high labor costs" argument. Once technological breakthroughs lead to a greater reduction in the cost of robots and a wider range of applications, machines will move from replacing part of the labor to completely replacing labor. Robotization has also led to a further increase in workers' alienation, degrading workers' skills, weakening their sense of labor control, and even becoming "machine guards," causing them to be deprived of their sense of value and creativity as workers. Their mental health and identity may also be negatively affected. The deeper impact is that with the polarization of job types and skills, the income gap between workers will continue to expand, while robot holders will accumulate wealth faster, and the widening gap between rich and poor may trigger wider social problems (Freeman 2016).

Let the majority of workers, especially underclass workers, achieve labor upgrades instead of becoming victims of the progress of the times. It cannot rely solely on laborers' input and self-improvement but also requires a common system design and resource input of the state and enterprises. This can be achieved only by calling on entrepreneurs and engineers to change the principles of economic rationality when designing technology but also by changing the incentives for the market economy (Ford 2015). However, judging from the current development trend, the advancement of China's intelligent manufacturing still emphasizes various support for enterprises and technological transformation (including mechanisms, fiscal and taxation, and finance), and there is a lack of integrated thinking on how to balance economic, technological, and human development. Government departments closely related to laborers, such as human resources and social security departments, and labor union departments, are almost absent in the policy formulation and implementation process of manufacturing upgrading and transformation, and there is a lack of consideration of their employment effects and labor market impact (Ernst 2016; Lüthje 2019). Whether the future of China's manufacturing industry is to make robots as the center and place workers under the control of technology or to develop a human-centered human–machine collaboration mechanism to protect the labor rights and interests of workers still depends on the arrangement of the social system and the formulation of public policies.

Abbreviations

CNC: Computer numerical control; IoT: Internet of Things; MES: Manufacturing execution system; OEM: Original equipment manufacturing; SCOT: Social construction of technology.

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Authors' contributions

Yi Xu designed the study, conducted research, analyzed material and wrote the article. Xin Ye contributed in data collection. All authors read and approved the final manuscript.

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Declarations

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References

Ackroyd, S., and P. Thompson. 1999. *Organization misbehaviour*. London: Sage.
Adler, P. 1992. *Technology and the future of work*. Oxford: Oxford University Press.
Botthof, A., and H. Ernst. 2015. *Zukunft der arbeit in Industrie 4.0*, Xin Liu translated. Beijing: China Machine Press.
Braverman, H. 1979. *Labor and monopoly capital: The degradation of work in the twentieth century*, Fang Sheng, Zhu Jijun, Wu Yixuan, Chen Weihe, and Zhang Qipian translated. Beijing: The Commercial Press.
Bright, J. 1958. *Automation and management*. Boston: Harvard University.
Burawoy, M. 2008. *Manufacturing consent: Changes in the labor process under monopoly capitalism*, Li Rongrongtranslated. Beijing: The Commercial Press.
Butollo, F., B. Lüthje and S. Luo. 2018. Made in China 2025-Interpretation of intelligent manufacturing and work in the global economy. *Chinese Annual Review of Political Science (2018)*, 81–99. Beijing: The Commercial Press.
Cheng, H., W. Chen, and T. Li. 2018. Robots in China: Status, future and impact. *Journal of Macro-Quality Research* 6(3): 1–21.
Edwards, R. 1979. *Contested terrain: The transformation of the workplace in the twentieth century*. New York: Basic Books.
Ernst, D. 2016. Advanced manufacturing and China's future for jobs. East-West Center Working Paper.
Ford, M. 2015. *Rise of the robots: Technology and the threat of a jobless future*, Wang Jimei and Niu Xiaomeng translated. Beijing: CITIC Press.
Freeman, R. 2016. Who owns the robots rules the world: The deeper threat of robotization. *Harvard Magazine* 2016(May June), 37–39.
Friedman, A. 1977. *Industry and labour*. London: Macmillan.
Hall, R. 2010. Renewing and revising the engagement between labour process theory and technology. In *Working life: Renewing labour process analysis*, ed. P. Thompson and C. Smith, 159–181. Basingstoke: Palgrave Macmillan.
Hirschhorn, L. 1984. *Beyond mechanization*. Cambridge, Mass: MIT Press.
Huang, Y., and N. Sharif. 2017. From "labour dividend" to "robot dividend": Technological change and workers' power in South China.". *Agrarian South: Journal of Political Economy* 6(1): 53–78.
Kelley, M. 1986. Programmable automation and the skill question: A reinterpretation of the cross-national evidence. *Human System Management* 6(3): 223–241.
Kelley, M. 1990. New process technology, job design and work organization: A contingency model. *American Sociological Review* 55(2): 191–208.
Liker, J., C. Haddad, and J. Karlin. 1999. Perspectives on technology and work organization. *Annual Review of Sociology* 25(1): 575–596.
Lü, R., and L. Hao. 2018. Research on the impact of artificial intelligence and other technologies on the labor market. *Journal of Industrial Technological Economics* 37(12): 131–137.
Lüthje, B. 2019. Platform capitalism "Made in China"? Intelligent manufacturing, Taobao villages and the restructuring of work. *Science, Technology & Society* 24(2): 199–217.
McKinlay, A., and P. Taylor. 1998. *Foucault, management and organization theory: From panopticon to technologies of self*. London: Sage.
Noble, D. 1984. *Forces of production: A social history of industrial automation*. New York: Knopf.
Penn, R. 1982. Skilled manual workers in the labor process 1856–1964. In *The degradation of labor? Skill, deskilling and the labor process*, ed. S. Wood, 90–108. London: Hutchinson.
Sewell, G. 1998. The discipline of teams: The control of team-based industrial work through electronic and peer surveillance. *Administrative Science Quarterly* 43(2): 397–428.
Thompson, P. 1989. *The Nature of Work*. London: Macmillan.
Thompson, P., and S. Vincent. 2010. Labor process theory and critical realism. In *Working life: Renewing labor process analysis*, ed. P. Thompson and C. Smith, 47–69. Basingstoke: Palgrave Macmillan.
Vallas, S. 1990. The concept of skill: A critical review. *Work and Occupation* 17(4): 379–398.
Xu, H. 2019. The end of the "global factory" model? Labor sociology perspectives on the scheme of "robots replacing human" in China. *Journal of Social Development* 6(1): 143–162.
Xu, Y., and H. Xu. 2019. The two models of robotization and their social influence: Technology upgrading. *Beijing Cultural Review* 2019(3): 88–96.
Zhang, Y. 2018. The impact of "robots replacing human" on labor employment in Beijing manufacturing—Based on case studies of six companies in Beijing. *Human Resources Development of China* 35(10): 136–146.

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