

From Repetition to Maintenance: How Digital Transformation in Chinese Manufacturing Reshapes Workers' Skill Requirements

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Abstract. In recent years, China's manufacturing sector has undergone rapid digital transformation, creating a growing demand for a workforce with capabilities relevant to smart manufacturing, while educational requirements for factory based positions are generally on the rise. However, existing research has focused primarily on job displacement and wage gaps, leaving the transformation of individual-level worker skill requirements largely under-explored, and failing to provide targeted actionable evidence for local vocational training system design. This paper examines how digital transformation shifts skill requirements for manufacturing workers in China from repetitive manual tasks toward machine operation, equipment maintenance, and digital systems management. This paper adopts a theoretical approach, drawing on existing academic literature and statistical data, supplemented by a practitioner interview with a Chinese manufacturing company owner, to examine how digital transformation in Chinese manufacturing reshapes workers' skill requirements. This paper finds that digital transformation contributes to a K-shaped labor market, where high-skill workers benefit while low-skill workers face displacement and wage stagnation. To adapt, manufacturing workers must develop new competencies including equipment operation, maintenance, and digital systems management. The paper further argues that targeted government vocational training policies and corporate training programs are essential to support workers through this transition.

Keywords: digital transformation, manufacturing workers, skill restructuring, China structural immobility, K-shaped labor market

1. Introduction

Driven by national strategies promoting new industrialization and smart manufacturing, China's manufacturing industry is undergoing a comprehensive digital and intelligent transformation. Automated production systems and digital management platforms have gradually replaced mass repetitive manual labour on traditional assembly lines. Factories now set higher competency standards for frontline staff, leaving workers who only master simple physical operations unable to match updated job demands. This structural mismatch between traditional labour capabilities and new industrial skill expectations has reshaped the internal structure of the manufacturing labour

market. With demand for smart manufacturing workers projected to exceed 31 million by 2035, and educational requirements for factory roles expected to rise from 28% to 57%, the scale of this transformation demands closer academic attention [1]. This paper examines how digital transformation reshapes skill requirements for manufacturing workers in China from repetitive manual tasks to maintenance, monitoring and digital system management.

This paper adopts a theoretical approach, drawing on existing academic literature and statistical data, supplemented by a practitioner interview with a Chinese manufacturing company owner, to examine how digital transformation in Chinese manufacturing reshapes workers' skill requirements. The findings have practical implications for policymakers, corporations, and workers navigating China's digital manufacturing transition, particularly in helping them understand and address the structural skill gap created by rapid automation. This research covers labour-intensive, technology-intensive, and other subsectors of Chinese manufacturing.

2. Literature review

Existing studies show that automation is increasingly reducing the demand for repetitive manual labour in Chinese manufacturing, as digital systems replace tasks that were previously performed entirely manually [2, 3]. At the same time, research identifies a growing gap between high-skill workers, who benefit from digitalization, and low-skill workers, who face wage stagnation and displacement [4, 5]. Empirical evidence suggests that automation has a significant negative effect on low-skill employment while simultaneously boosting demand for high-skill workers, with studies reporting employment coefficients of -0.295 and +0.159 respectively [3]. Understanding how skill requirements shift at the worker level is essential because it can directly inform government policy decisions and corporate training strategies aimed at supporting workers through this transition. In response to these shifts, the Chinese government has actively promoted smart manufacturing and invested in digital upskilling to prepare workers for the demands of an increasingly digitized manufacturing sector [6, 7]. However, existing literature has focused primarily on macro level employment data and industry wide wage gaps, with very few studies examining the specific skill transformation directions at the level of frontline workers' day-to-day job operations, leaving this dimension largely under-explored.

Studies on China's lighthouse factories further demonstrate that leading firms have already begun implementing advanced digital skill requirements, serving as benchmarks for the broader manufacturing sector [8]. For example, lighthouse factories designated by the World Economic Forum have introduced AI-driven quality inspection, automated logistics, and real-time data analytics, requiring workers to operate systems that go far beyond traditional manual competencies. These developments suggest that digital literacy, including the ability to interpret production data, navigate enterprise software, and respond to automated system alerts, is rapidly becoming a foundational requirement across China's manufacturing sector, rather than a specialist skill confined to technical roles [6, 7].

3. Theoretical framework

3.1. Skill polarization & K-shaped labor market

Skill polarization theory argues that automation simultaneously raises the demand for high-skill workers while reducing the demand for low-skill workers, resulting in a widening wage gap [4, 5]. While skill polarization theory was originally developed in the context of Western economies, this

dynamic contributes to a K-shaped labour market, in which firms increasingly retain workers who are digitally capable while reducing reliance on workers whose roles are limited to repetitive manual tasks [4, 8]. In the context of Chinese manufacturing, this dynamic creates a K-shaped labor market, where firms increasingly retain workers who are digitally capable, while displacing those whose roles are limited to repetitive manual tasks [4, 8]. Unlike the broader global narrative of skill polarization, China's K-shaped labor market is shaped by distinctive domestic factors, including rapid state-driven automation, a large migrant worker population, and institutional barriers such as the hukou system, making it a uniquely Chinese manifestation of a global phenomenon. This polarization is reflected in rising educational requirements for factory roles, which are projected to increase from 28% to 57%, suggesting that opportunities for semi-skilled work are becoming increasingly limited [1]. As opportunities for semi-skilled work decline, workers who cannot transition may face greater risks of unemployment, while those who successfully upskill may move into better-paid, higher-value roles. This wage divergence is not merely theoretical - empirical studies confirm that the digital economy has significantly widened the gap between high and low-skilled workers' earnings in China, with automation found to have an employment coefficient of -0.295 for low-skill workers and +0.159 for high skill workers, directly quantifying the scale of this divergence [3-5]. This polarization is particularly pronounced in coastal manufacturing hubs such as Guangdong and Zhejiang, where rapid state-driven automation has accelerated the divergence between high-skill and low-skill workers, placing these regions at the forefront of China's K-shaped labour-market transformation [4, 5].

3.2. Structural immobility

Schewel's concept of structural immobility explains why low-skill workers often cannot upskill, even when they aspire to do so, because they lack the financial resources, educational access, and training opportunities needed to make the transition. Unlike voluntary immobility, where workers choose not to move, structural immobility is involuntary driven by constraints such as poverty, lack of access to training, and geographic isolation that prevent workers from transitioning to higher-skill roles. In the context of Chinese manufacturing, structural immobility is particularly acute for migrant workers, who are concentrated in lower-skill roles and face substantial barriers to accessing retraining programs [7]. Without targeted efforts to address structural immobility, the gap between high-skill and low-skill workers may continue to widen, deepening inequality within China's manufacturing workforce [7]. In China, this structural immobility is further compounded by the hukou household registration system, which restricts migrant workers' access to urban public services including vocational training programs [7]. In addition to the household registration system, many low-skill workers face additional compounding barriers including financial pressure to prioritize immediate income over retraining, family caregiving obligations that limit time available for study, and geographic distance from urban training centres that makes participation logistically difficult even when programs are theoretically available [7].

4. Shifts in worker skill requirements driven by digital transformation

4.1. Repetitive tasks to machine operations

Prior to digital transformation, manufacturing workers in China primarily performed repetitive manual tasks, with many production processes relying heavily on manual labour [2]. Digital transformation now requires workers to operate automated equipment, monitor production data, and

input commands into digital control systems [9]. In practice, this includes operating computer numerical control (CNC) machines, programming automated assembly lines, and monitoring real-time production data through digital control panels [9]. This represents a dramatic shift in training requirements. While traditional assembly line workers in the manual era required only one to two days of training before commencing work, gaining proficiency in operating automated equipment today demands an average of approximately five weeks of systematic training. The scale of this transition is substantial. Demand for smart manufacturing workers in China is projected to exceed 31 million by 2035, highlighting the growing need to equip workers with new operational competencies [1]. Workers who master these machine operations become increasingly important to their firms, as their ability to manage automated systems directly determines production output and efficiency [9]. However, this transition is not equally accessible to all workers—older workers and those with lower levels of prior education often struggle to adapt to the demands of automated equipment operation, requiring additional digital literacy support and longer training periods before reaching operational competency [6].

4.2. Manual labor to equipment maintenance

As manufacturing equipment becomes increasingly automated, workers are now expected to identify technical faults, perform routine maintenance checks, and report or resolve equipment malfunctions [9]. This represents a significant shift from purely physical labor to technical and digital problem-solving, requiring workers to develop basic troubleshooting and diagnostic skills [9]. Workers who are unable to develop these maintenance competencies may face a greater risk of displacement, as firms increasingly prioritize technically skilled staff over those limited to manual physical tasks [6]. Firms that invest in maintenance training for their workers see measurable improvements in production efficiency, as workers who can identify and resolve faults quickly reduce costly downtime [10]. Increasingly, workers are also expected to perform predictive maintenance by using sensor data and digital monitoring systems to anticipate equipment failures before they occur [9]. These maintenance expectations apply specifically to frontline workers and cover basic fault identification, routine upkeep, and simple troubleshooting while more advanced deep equipment repairs remain the responsibility of specialist technical roles [9]. This shift toward predictive maintenance represents a significant competitive advantage for firms by identifying potential failures before they cause production stoppages, workers with these skills directly contribute to reducing operational costs and improving overall equipment effectiveness, making maintenance competency a measurable driver of firm-level productivity [9, 10].

4.3. No digital skills in digital systems management

These digital systems include enterprise resource planning (ERP) platforms, manufacturing execution systems (MES), and real-time data dashboards that require workers to interpret and act on production analytics [9]. Beyond operating individual machines, digital transformation requires workers to navigate digital platforms, analyze production data, and manage smart manufacturing systems [9]. This is supported by evidence from a semi-structured interview conducted for this study with the owner of a small-to-medium-sized Chinese petrochemical manufacturing company. The interview explored questions including whether new machinery or automation had been introduced, how worker responsibilities had changed from those of the past, whether educational or skill requirements for new hires had risen, and whether any workers had left or been replaced due to inability to operate new equipment. The interviewee noted that digitalization has created a big data

environment in which workers must continuously upskill as captured in the expression "bu jin ze tui," roughly meaning "those who do not move forward will fall behind." This demand for digital systems management represents the clearest expression of a K-shaped labor market workers who master these skills move upward, while those who do not move downward into displacement and wage stagnation [4, 8]. Workers who cannot manage digital systems risk becoming increasingly vulnerable in the digital economy, as their inability to navigate smart manufacturing platforms makes them increasingly difficult to employ [11]. Digital literacy has therefore emerged as a baseline requirement for manufacturing employment, rather than an advanced or optional competency; workers who lack the ability to read data dashboards, input commands into digital systems, or interpret automated alerts are already being screened out at the hiring stage, before they even reach the factory floor [4, 5].

5. Discussion and policy implications

The findings suggest that digital transformation is reshaping the Chinese manufacturing labour market by increasing skill requirements and raising entry barriers for workers. A key structural challenge is the persistent mismatch between the skills taught in China's vocational schools and the competencies demanded by digitally transformed manufacturing firms; many vocational curricula remain oriented toward traditional manual operations, leaving graduates underprepared for the digital systems management, predictive maintenance, and data interpretation skills that modern factories now require [7, 8].

In response to digital transformation, the Chinese government has actively promoted smart manufacturing while simultaneously investing in vocational retraining programs to support displaced low-skill workers [7]. However, government policy alone may not be sufficient. Many workers continue to face structural barriers such as poverty, limited access to training, and geographic isolation, which can prevent them from accessing these programs even when they are available [7]. This suggests that while government intervention is a necessary first step, it must be complemented by corporate and worker-led initiatives to ensure that the most vulnerable workers are not permanently excluded from the digital economy.

At the corporate level, leading Chinese manufacturing firms have demonstrated that internal digital training programs can successfully prepare workers for the demands of smart manufacturing, suggesting that corporate investment in upskilling is essential to bridging the skill gap [10]. One practical model that manufacturing firms could adopt is a progressive, mentorship-based training system in which experienced frontline workers with established digital skills serve as internal trainers for newer employees. This peer-led approach leverages existing in-house expertise, reduces training costs, and ensures that skill transfer is grounded in the practical realities of the factory floor rather than abstract classroom instruction. Beyond government and corporate efforts, some workers have sought training independently, as seen in initiatives like the Ningbo New Workers' Night School, where over 28,000 workers voluntarily enrolled in skills training after work hours. The program offers free courses covering a range of practical skills including CNC machine operation, equipment maintenance fundamentals, digital platform navigation, and workplace safety certification, helping workers who face barriers to formal education access structured professional development on their own terms. Such grassroots initiatives suggest that when formal pathways are inaccessible, workers demonstrate agency by seeking out learning opportunities on their own, challenging the assumption that upskilling depends entirely on government support or corporate training.

Although government-, corporate-, and worker-led initiatives provide pathways for upskilling, workers who face poverty, limited training access, and geographic isolation remain unable to access these opportunities; a condition Schewel describes as structural immobility. Without targeted efforts to remove these structural barriers, large numbers of low-skilled manufacturing workers may face a heightened risk of being left behind in China's digital economy. This suggests that effective policy must go beyond creating training programs; it must also address the structural barriers that prevent the most vulnerable workers from accessing them in the first place. Failure to do so risks entrenching a permanent underclass of displaced workers, undermining both social equity and China's long-term economic competitiveness.

6. Conclusion

This paper has argued that digital transformation in Chinese manufacturing does not simply eliminate jobs, but fundamentally reshapes skill requirements at the worker level, shifting expectations from repetitive manual tasks to equipment maintenance, monitoring and digital systems management. Through the lens of skill polarization theory, this transformation produces a K-shaped labor market in which high-skill workers gain new opportunities, while low-skill workers risk being permanently left behind due to structural immobility. These findings suggest that policy attention must shift from employment numbers alone toward targeted support for skill transitions, ensuring that workers who face structural barriers to retraining are not permanently excluded from the digital economy. In particular, policymakers should prioritize reforming vocational school curricula to better reflect the digital competencies now demanded by manufacturing firms, ensuring that graduates enter the workforce equipped with practical skills in equipment operation, maintenance, and digital systems management rather than outdated manual production techniques. Further research should employ longitudinal studies to examine workers' long-term outcomes, including mobility, wages, and access to retraining, in order to better understand the lasting effects of digital transformation on China's manufacturing workforce. As a theoretical analysis drawing primarily on secondary data and a single practitioner interview, future research should employ larger-scale surveys and longitudinal data to validate these findings across different manufacturing sectors and regions.

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