The Impact of Autonomous Driving Popularization on Taxi Workers: A Multidimensional Analysis Based on the Substitution–Creation–Transition Framework

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ABSTRACT:

As autonomous driving technology iterates rapidly and commercial pilot programs continue to expand, the taxi industry—one of the labor-intensive service sectors most immediately exposed to the risk of autonomous substitution—has seen the employment shocks facing its workforce become a practical issue of shared concern in both academia and policy circles. Drawing on theories of technological unemployment and research on the service economy, this paper adopts a qualitative method combining literature analysis and policy text analysis to systematically examine the impact of autonomous driving popularization on taxi workers across four dimensions: employment quantity, employment structure, income and the labor process, and skill requirements. The study finds that the impact presents a composite pattern of "aggregate substitution, structural differentiation, process reconstruction, and skill upgrading"; that the substitution process is constrained by technological maturity, regulatory pacing, cost curves, and social acceptance, and therefore unfolds gradually rather than abruptly; and that the creation of new jobs concentrates in remote supervision, safety operation, vehicle maintenance, and service management, yet a significant skill mismatch exists between these positions and incumbent drivers. Accordingly, policy recommendations are proposed at the levels of government, enterprises, and the industry, covering gradual transition, social security backstops, reskilling, and the design of transition channels.

Keywords: autonomous driving; taxi workers; technological unemployment; job displacement; reskilling

1.INTRODUCTION

Autonomous driving technology is moving from closed-course testing toward commercial operation on open roads. In recent years, many countries and regions have successively issued

regulations governing the road testing and operation of autonomous vehicles, and driverless taxis (robotaxis) have begun carrying passengers in demonstration programs in several cities. China has also elevated intelligent vehicles to a national strategic industrial direction: in 2020, the National Development and Reform Commission (NDRC) and other departments jointly issued the Intelligent Vehicle Innovation and Development Strategy, explicitly setting the goal of achieving large-scale production of conditionally autonomous vehicles by 2025 (NDRC et al., 2020).

The taxi industry is regarded as a frontier scenario for the commercial deployment of autonomous driving because of its relatively controllable operating routes, the high share of driver labor in per-vehicle cost structures, and the deep platformization of dispatching. At the same time, the large population of taxi and ride-hailing drivers constitutes one of the occupational groups most directly and intensively exposed to the impact of autonomous driving. In their seminal study, Frey and Osborne (2017) estimated that the probability of taxi drivers' jobs being computerized exceeds 89%, ranking among the highest of all occupations.

Existing studies mostly focus on the technological evolution path of autonomous driving, market size projections, or transportation system effects, while systematic discussion of the micro-level subject—the workers themselves—remains relatively scarce: when substitution will occur, in what manner, which segments will be affected, and how workers can transition still lack an integrated analytical framework. Accordingly, this paper seeks to answer three questions. First, to what extent and at what pace will the popularization of autonomous driving substitute for taxi workers' existing jobs? Second, will job substitution be accompanied by the creation of new jobs and the restructuring of employment? Third, how should governments, enterprises, and the industry design transition mechanisms to reduce the social costs of transformation?

The significance of this study is twofold. Theoretically, it applies the analytical framework of technological unemployment to a highly platformized urban mobility service industry and refines the mechanism chain of "substitution–creation–transition." Practically, it provides a reference for relevant authorities in formulating gradual regulatory policies, social security policies, and vocational training policies.

2.LITERATURE REVIEW

2.1 Aggregate Estimates of Automation and Job Displacement

Regarding the employment effects of automation, the literature is divided between "substitution pessimism" and "creation optimism." Based on probabilistic estimates of the computerizability of occupational tasks, Frey and Osborne (2017) argued that about 47% of jobs in the United States fall within a high-risk range—a judgment that sparked extensive debate. In contrast, after examining task heterogeneity at the worker level, Arntz et al. (2016) found that only about 9% of jobs in OECD countries face a high risk of substitution, significantly lower than occupation-level estimates. From a historical perspective, Autor (2015) observed that while automation replaces some tasks, it also continuously generates employment demand by raising productivity, creating new tasks, and strengthening human complementarity—"why are there still so many jobs" epitomizes the long-run coexistence of technology and employment. Brynjolfsson and McAfee (2014) characterized the current stage as the "second machine age," arguing that digital technologies are penetrating cognitive and physical tasks at an unprecedented speed and that the speed and breadth of employment restructuring will surpass all previous technological revolutions.

Acemoglu and Restrepo (2019) further proposed the analytical framework of "displacement effect–productivity effect–new task creation": automation directly substitutes for labor tasks, but productivity gains and the creation of new non-automated tasks partially reinstate employment. Using cross-country industry data, Graetz and Michaels (2018) showed empirically that the use of industrial robots raised productivity and wages without reducing total employment, though its structural effects were significant—low-skilled workers were relatively disadvantaged. Manyika et al. (2017) estimated that by 2030, 400 to 800 million workers worldwide might have their jobs displaced by automation while substantial new occupational demand would emerge; large-scale job transitions and retraining thus constitute the core challenge.

2.2 Autonomous Driving and Employment in Mobility Services

In the mobility service sector, Fagnant and Kockelman (2015) were among the first to systematically discuss the macro-level benefits of autonomous vehicles and the required policy preparations, noting that while reducing accident rates and travel costs, they would also exert

an impact on professional driver groups. Manyika et al. (2017) ranked "driving" among the physical task categories most susceptible to automation and estimated that about 3 million jobs in the United States with driving as the primary duty face long-term substitution risk. From a public policy perspective, Grush et al. (2018) argued that the cost advantage of autonomous mobility services would gradually erode the landscape in which private cars and taxis coexist, and that policy design should proactively incorporate social arrangements for driver transition.

In contrast to the substitution thesis, research from a service interaction perspective offers a different view. Based on frontline service contexts, Wirtz et al. (2018) pointed out that service segments involving empathy, complex communication, and situational judgment will remain difficult for service robots to fully replace in the foreseeable future, suggesting that the substitution boundary of hybrid "driving plus service" jobs is not monolithic. The public survey by Smith and Anderson (2017) found that most Americans remain hesitant about riding in fully self-driving cars, indicating that social acceptance constitutes a realistic constraint on technology diffusion.

2.3 Platformized Labor and the Employment Characteristics of Taxi Workers

The contemporary taxi industry is highly platformized. Rosenblat's (2018) research on ride-hailing platforms reveals the deep penetration of algorithmic management into drivers' labor processes: dispatch rules, dynamic pricing, and rating systems improve matching efficiency while making drivers' income increasingly unstable and eroding their labor autonomy. This means that even before autonomous driving substitution occurs, the employment form of taxi workers has already undergone a round of profound restructuring; the shock of autonomous driving will be superimposed upon these existing vulnerabilities. Litman (2023), in his continuously updated assessment, emphasizes that market penetration of autonomous vehicles will be a gradual process spanning decades: workers need not panic in the short term, but policy preparation cannot begin too early.

2.4 Commentary

Existing research has established the theoretical framework of "substitution–creation–transition," made overall judgments on the risk of autonomous driving substituting for professional drivers, and characterized industry employment features from the platform labor perspective. However, the limitations of the existing literature are also evident: most studies

discuss aggregates at the national or industry level and rarely examine the multidimensional impacts on the specific occupational group of taxi workers; the constraints on the pace of substitution lack integrated review; and discussions of transition channels and policy instruments largely remain at the level of principles. This paper seeks to advance the literature in these three respects.

3.ANALYTICAL FRAMEWORK AND RESEARCH METHODS

3.1 Analytical Framework

This paper constructs an analytical framework of "four-dimensional impacts–constraints–transition mechanisms." The four dimensions of impact include: (1) employment quantity, i.e., the scale and pace at which existing jobs are substituted; (2) employment structure, i.e., the differentiation of job types and the distribution of newly created positions; (3) income and the labor process, i.e., the reshaping of workers' labor conditions by algorithmic management and operational model changes; and (4) skill requirements, i.e., changes in the occupational skill spectrum and their degree of match with the existing human capital stock. The constraints cover four aspects—technological maturity, regulation and access policy, operating cost curves, and social acceptance—which jointly determine the speed and path of substitution. The transition mechanisms examine workers' reallocation channels at the levels of government, enterprises, and the industry.

3.2 Research Methods

Given the forward-looking nature of the topic and the limited availability of micro-level panel data, this paper adopts a qualitative research method combining literature analysis and policy text analysis: journal articles from authoritative databases and reports from international organizations and consulting institutions serve as the literature sources, while regulatory policy texts on autonomous driving in China and other major countries serve as the objects of policy analysis; thematic coding is used to induce the impact mechanisms and policy essentials. This method is suitable for mechanism identification and proposition refinement; its limitations are explained in the conclusion.

4.DIRECT IMPACTS OF AUTONOMOUS DRIVING POPULARIZATION ON TAXI WORKERS

4.1 Employment Quantity: Aggregate Substitution Pressure and a Gradual Pace

In terms of substitution potential, the high routinization of driving tasks places them durably within the high-risk range of task-based substitution models (Frey & Osborne, 2017), and the core task chain of taxi operation—"driving plus passenger service"—is precisely one of the most mature directions for the commercial deployment of autonomous driving (Grush et al., 2018). If the per-kilometer cost of driverless taxis falls below that of human-driven vehicles at scale, market forces will drive the contraction of existing jobs—a process that can occur spontaneously, without administrative mandates.

In terms of pace, however, substitution will be gradual rather than abrupt. First, technological constraints: complex weather, non-standard road conditions, and long-tail scenarios still require time to resolve (Fagnant & Kockelman, 2015). Second, regulatory constraints: licensing for passenger operations, determination of accident liability, and insurance systems are still under construction. Third, cost constraints: sensor and vehicle costs, together with the cost of configuring remote safety operators, mean that the cost advantage of fully driverless operation is not yet secure in the short term (Litman, 2023). Fourth, social constraints: public trust in fully driverless vehicles takes time to build (Smith & Anderson, 2017). Synthesizing existing projections (Manyika et al., 2017; Litman, 2023), the following judgment can be made: over the next 5–10 years, substitution will mainly occur in demonstration operations in pilot cities and in specific scenarios (such as airport shuttle lines and fixed areas), with limited aggregate impact; between 10 and 20 years, as cost curves decline and regulation matures, substitution will enter an accelerating phase, at which point the job-transition pressure on incumbent drivers will become concentrated and pronounced.

4.2 Employment Structure: Job Differentiation and the Distribution of New Positions

Substitution is not merely the elimination of jobs; it is accompanied by the restructuring of the occupational structure. Following the new-task framework of Acemoglu and Restrepo (2019), autonomous mobility services will spawn several non-automated new positions: first, remote supervision and safety operation positions, including remote safety operators, dispatch coordinators, and emergency response specialists; second, vehicle operation and maintenance

positions, covering the calibration, testing, cleaning, and charging maintenance of autonomous driving systems; and third, on-site service positions, such as vehicle inspection, in-cabin order management, and passenger assistance. The projections of the World Economic Forum (2023) likewise indicate that the green transition and the application of artificial intelligence will create large numbers of new jobs while displacing others, but the skill composition of the new jobs differs significantly from that of the displaced ones.

For taxi workers, the problem lies in structural mismatch: the new positions either require system maintenance and data processing skills or stronger emergency response and communication abilities, while the skill stock of incumbent drivers—centered on driving skills—cannot be directly transferred. Older and less-educated groups face particularly narrow re-employment channels, making them the most vulnerable groups in this structural differentiation and the ones most in need of policy attention.

4.3 Income and the Labor Process: A Second Restructuring from Algorithmic Management to Human–Machine Collaboration

Before full substitution occurs, autonomous driving technology has already penetrated the labor process in the form of "human–machine collaboration." The deepening of assisted driving functions, intelligent dispatching, and dynamic pricing increasingly embeds drivers' labor within algorithmic systems. The logic of algorithmic management revealed by Rosenblat (2018)—data-driven performance evaluation and opaque rule changes—will be further strengthened in the era of autonomous driving: when the vehicle itself becomes the executor of algorithms, the human role is compressed into that of "exception handler" and "service supplement," and both bargaining power and professional identity may be weakened.

At the income level, a two-stage pattern emerges. During the transition period, some platforms may reshape positions under the title of "safety operator," but such positions often offer lower hourly wages and more demanding work arrangements than traditional driving jobs, and they themselves face a "second substitution" risk as the technology matures. After the acceleration phase of substitution, workers who fail to transition face the risk of income interruption, while those who successfully move into new positions in maintenance and supervision may see their income curves stabilize or even rise. Income differentiation will thus be isomorphic with skill differentiation.

4.4 Skill Requirements: The Leap from Driving Skills to Composite Skills

The popularization of autonomous driving will systematically reshape the skill spectrum of mobility service occupations. Traditional positions center on driving operation skills, supplemented by route experience and basic service abilities; the new positions feature a composite structure of "technical understanding plus emergency response plus service communication." The research of Wirtz et al. (2018) suggests that service content involving emotional labor and complex interaction remains a comparative advantage of humans in the long run, which means that the depreciation of "driving skills" does not equal the depreciation of "service capabilities"—workers' transition paths do not all lead to technical positions; a considerable proportion will shift toward service positions centered on interpersonal interaction.

For individuals, reskilling faces three obstacles: information asymmetry between training supply and job demand, the opportunity cost incurred during training, and the constraints of age and learning curves. Without external support, market-based training will systematically favor younger and more educated groups, exacerbating the distributional inequality of the transition (Manyika et al., 2017).

5.INDIRECT AND SYSTEMIC IMPACTS

5.1 Transmission Effects on the Labor Market

The scale and mobility of the taxi driver population mean that the shock will not be confined to the industry itself. This group consists largely of rural migrant workers and flexible workers with low social security participation rates and weak risk resilience; once substitution accelerates, the shock will transmit outward along the chain of "household income–consumption–local service industries." Moreover, professional drivers constitute one of the most emblematic cases of automation-era displacement, and the success or failure of their transition will become a reference frame for public evaluation of automation policies, carrying social-psychological significance that extends beyond the industry.

5.2 Impacts on Urban Transportation and Informal Employment

If autonomous mobility services significantly reduce travel costs, they may induce growth in total travel demand and thereby create some derivative service demand (Fagnant & Kockelman, 2015); they may also squeeze the space of informal employment such as unlicensed taxis and motorcycle taxis, altering the stock structure of urban informal employment. In

addition, a “dual-track” pattern may emerge during the industry transition—human-driven and driverless vehicles coexisting for an extended period under asymmetric competitive rules—and how to prevent incumbent workers from being cleared out too quickly under such asymmetric competition is a question that regulatory design must address (Grush et al., 2018).

6.POLICY RECOMMENDATIONS

6.1 Government Level: Gradual Transition and Social Security Backstops

First, implement gradual management of the substitution pace. When issuing driverless operation licenses, set protective clauses for incumbent workers, such as requiring operators to allocate transition positions proportionally and establishing transition periods and regionally phased substitution arrangements, so as to avoid “shock-style” clearance. Second, strengthen social security backstops. In view of the low insurance participation rate of the driver population, expand occupational injury insurance coverage for flexible workers and provide seamless linkage between unemployment insurance and reemployment services for those who lose their jobs during the transition. Third, build a reskilling system. Include professional drivers in special job-transition training programs, develop curricula around three directions—remote safety, vehicle maintenance, and passenger service—and provide training and living subsidies to reduce opportunity costs. Fourth, improve the recognition of new occupations. Incorporate emerging positions such as remote safety operators and autonomous driving maintenance technicians into the occupational classification and skill certification systems, opening up career development channels for workers.

6.2 Enterprise Level: Internal Reallocation and Shared Responsibility

Operators and technology service enterprises should incorporate labor transition into their commercialization plans: prioritize recruiting remote safety operators and on-site service staff from incumbent drivers, and establish an internal transition ladder of “driver–safety operator–maintenance technician”; retain appropriate human–machine collaboration interfaces in technical designs to slow the pace at which full driverlessness compresses jobs. Meanwhile, enterprises should build targeted training mechanisms jointly with vocational colleges, internalizing the costs of transition as human capital investment rather than externalizing them as social problems.

6.3 Industry and Individual Levels: Organizational Support and Proactive Transition

Industry associations can serve as information hubs by publishing monitoring reports on substitution progress and job demand lists, thereby reducing individuals' information asymmetry. Individual workers, for their part, should plan early: during the transition period, they should accumulate service and emergency response skills, obtain relevant qualifications, and proactively move toward newly created positions or related industries (such as freight dispatching, the automotive aftermarket, and elderly care services) rather than passively waiting for substitution to occur.

7.DISCUSSION AND CONCLUSION

Based on the "substitution–creation–transition" framework, this paper has analyzed the impact of autonomous driving popularization on taxi workers across four dimensions: employment quantity, employment structure, income and the labor process, and skill requirements. Three core conclusions emerge. First, substitution is certain, but its pace is gradual: the fourfold constraints of technology, regulation, costs, and social acceptance determine a substitution path of "pilot scenarios first, stock markets later." Second, the essence of the shock is structural: aggregate substitution and job creation proceed in parallel, and the mismatch between the skill requirements of new jobs and the existing human capital stock constitutes the principal aspect of the contradiction. Third, the social costs of the transition can be significantly reduced through policy design: gradual transition, security backstops, and reskilling constitute the three pillars of the policy mix.

This study has the following limitations: literature analysis and policy text analysis lack first-hand survey data from workers, and the impact mechanisms await empirical testing; judgments about the pace of substitution rely on existing projection literature and carry high uncertainty; and the comparative perspective is confined to the taxi industry, excluding other driving occupational groups such as bus and freight drivers. Future research can examine employment elasticities and policy effects during the substitution process through tracking surveys and quasi-natural experiment designs, providing evidence for dynamically adjusting the policy mix.

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