Technology Empowerment and Responsible Governance: Optimization Path and Empirical Research on the Tripartite Game of Takeaway Platforms

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Abstract: Under the background of the rapid development of Internet technology and platform economy, the takeaway industry, being a typical multilateral market, presents a complex pattern of interest game. The takeaway platform connects consumers, merchants and riders, and while this model brings convenient consumption experience, it also exposes many problems of imbalance in the tripartite game. The contradictions between consumers' rights and interests, riders' occupational risks and platforms' responsibility boundaries are becoming more and more prominent, forming a crisis of trust and labor-management dilemma that restricts the sustainable development of the industry. Existing researches have theoretical blind spots in the design of dynamic game mechanism and innovation of platform governance paths, and there is an urgent need to build a synergistic governance framework that takes into account both efficiency and fairness. This study deeply analyzed the Stackelberg game model between takeout platforms and riders, the tripartite evolutionary game model of takeout platform-rider-consumer, and the tripartite evolutionary game model of value co-creation for stakeholders of takeout platforms. The study found that: (1) under the risk sharing mechanism, the platform could reduce the risk of riders' delivery speed by increasing the proportion of traffic risk sharing (the accident rate decreased by 18%), which verifies the positive incentive effect of the risk sharing mechanism on safe delivery; (2) through the simulation of the evolutionary game, the threshold design of the overtime compensation mechanism could form a three-party strategic Nash equilibrium, which could realize the strategic equilibrium of the platform, riders and consumers (complaint rate (23% reduction in complaint rate); (3) Based on the empirical evidence, the effectiveness of the "algorithm transparency-responsibility clarity-data security" trinity governance framework was verified. The results of the study provide effective governance ideas for the takeaway platform to deal with the tripartite relationship, offer new theoretical perspectives and practical paths to promote the healthy development of the platform economy, crack the dilemma of value distribution in the platform economy, and provide important insights into the construction of a new type of labor-management relations in the digital era.

Keywords: Takeaway Platform; Stackelberg Game; Evolutionary Game; Risk Sharing; Algorithm Transparency

1. Introduction

China's sharing economy market has shown continuous expansion in the wave of digitization, with the market size reaching RMB 3.69 trillion in 2021 [1] and climbing to RMB 3.83 trillion in 2022, growing 2.14% year-on-year, according to the "Panorama of China's Sharing Economy Industry in 2024". Among them, the takeaway industry, as a typical representative, has realized a breakthrough growth of ten million orders per day through the flexible labor mode. However, the triple contradiction of damaged consumer rights and interests, sharp increase in business pressure and lack of labor protection for riders has become increasingly prominent. Judicial data shows that in 2022, there were more than 2,500 labor disputes involving takeaway riders nationwide, while lawsuits over false evaluations, delivery delays, and food safety

issues were frequent, exposing a systemic imbalance in the platform's governance mechanism and risk control system.

Current research focuses on the rights and interests of platform workers, consumer protection and other rights and interests of a single subject, but has not yet systematically analyzed the dynamic game of the three parties involved, and the combination of technological empowerment and institutional synergy is insufficient. By systematically sorting out and analyzing the game models related to takeaway platforms and constructing a tripartite dynamic game model, this study provides useful ideas and suggestions for the development of the industry, and promotes the formation of a multi-win sustainable development ecology.

2. Literature Review

2.1 Dilemmas and Theoretical Challenges of Evaluation Systems

As the core link connecting consumers, merchants and riders, the evaluation system of takeaway platforms has a direct impact on the sustainable development of the platform ecology in terms of its authenticity and referability. However, existing research points out that there were two core problems of information asymmetry and conflict of interest in the evaluation system [2]. On the one hand, it was difficult for consumers to obtain complete information about the efficiency of merchants' food delivery and the risk of riders' delivery, which led to the evaluation being easily misled by false content; on the other hand, merchants might brush positive reviews in order to improve their rankings, consumers might misuse the mechanism of bad reviews due to emotional feedback, and riders might sacrifice their service quality in order to avoid penalties. The imbalance of this three-way game was essentially the result of the non-neutrality of the platform's algorithm and the blurring of the subject of responsibility.

2.2 Evaluation Optimization Path under the Perspective of Game Theory

To address the above problems, scholars have proposed two types of solutions from the game theory perspective:

Stackelberg game model: platforms as leader's influence rider behavior through algorithmic rules. The study showed that when the platform bears more than 60% of the rider's transportation risk cost, the probability of the rider choosing a safe delivery speed is increased by 45%, thus reducing the bad reviews caused by speeding.

Three-party evolutionary game model: By constructing a dynamic strategy model for platforms, riders and consumers, it is found that the threshold design of the overtime compensation mechanism (compensation amount ≥15% of the order amount) can induce the three-party strategies to converge to the ideal equilibrium, i.e., the platform actively compensates, the rider delivers with low risk, and the consumer complains rationally [3].

2.3 Limitations of Technological Empowerment and Ethical Controversies

Although AI and big data technologies provide tools to optimize the rating system (e.g., sentiment analysis to identify fake reviews), their application still faces the risks of algorithmic discrimination and privacy leakage. Studies have pointed out that the "black box" nature of platform algorithms might lead to unreasonable manipulation of consumer rating weights, exacerbating information asymmetry. In addition, data encryption technology (e.g., IPSec VPN) could guarantee the security of evaluation transmission, but could not completely eliminate the technical loopholes of merchants brushing positive reviews [1].

2.4 Theoretical Orientation of this Paper

Existing research focuses on the behavior of a single subject or static game analysis, and lacks a systematic exploration of the three-party dynamic interaction and technology-institution synergistic mechanism. This paper integrates the risk sharing mechanism of the Stackelberg game and the threshold design theory of the evolutionary game, proposes the trinity governance framework of "algorithmic transparency-responsibility clarity-data security", and constructs a dynamic governance model.

3. Analysis of the Current Situation: Tripartite Conflicts and Game Imbalance

3.1 Rider Side: The Dilemma of High Risk and Low Protection

The occupational risk and lack of rights and interests of takeaway riders have become a typical contradiction in the platform economy. Data show that in 2022, traffic accident disputes

involving takeaway riders accounted for 31.4% of the total number of disputes, with frequent collisions due to complex road conditions during peak hours, and frequent falls and injuries in bad weather, and riders facing direct personal injuries such as broken bones and abrasions [2]. In addition, riders' income fluctuates significantly depending on the time of day, season, and region: morning and evening peak orders account for more than 60% of the total, while the order density in remote areas is less than 5%, which is superimposed on the platform's frequent adjustments to the rules of the commission (e.g., the incentive policy is changed 2.3 times per month on average), resulting in very poor stability of the income [1]. The deeper contradiction stems from the algorithm oppression: the platform for the pursuit of delivery efficiency, through the harsh time rules (such as "overtime 1-minute penalty of 3 yuan") and the complex logic of dispatching orders to force the rider speeding, retrograde, caught in the "safety - performance" dilemma game.

3.2 Merchant Side: The Double Pressure of Vicious Competition and Quality Compromise

In order to compete for limited traffic, merchants are caught in a vicious cycle of low price dumping and false marketing. According to the survey, 30% of merchants improve their rankings by brushing orders and fictitious favorable comments, and 15% of merchants promote their products at below-cost prices, resulting in the industry's profit margin dropping to 8%. Meanwhile, takeaway platforms' mandatory requirements on meal delivery time (e.g., "15-minute delivery rate ≥ 90%") force merchants to simplify the production process, with 60% of merchants admitting to using pre-prepared dishes or low-quality ingredients to shorten the time required to deliver the meal, which poses a direct threat to food safety. This "efficiency-first" orientation makes it difficult for merchants to balance quality and speed, further exacerbating the consumer trust crisis.

3.3 The Consumer Side: The Dual Dilemma of Declining Experience and Lack of Rights Defense

The problem of damaged consumer rights and interests is becoming more and more prominent:

- Delivery delay: the delay rate of orders during peak hours exceeds 15%, and the delay rate doubles in bad weather;
- Food safety hazards: 123,000 takeaway food safety complaints in 2022, 30% of which involved expired ingredients;
- Scoring mechanism distortion: the rate of false positive reviews accounted for 22%, the rate of malicious bad reviews accounted for 8%, the scoring reference value is lost.

More seriously, the platform responsibility is vague and data opacity leads to difficulties in defending rights: 70% of consumer complaints cannot be resolved due to mutual shirking of responsibilities by the platform, merchants and riders, and the platform algorithm black box (such as traffic allocation rules) makes it difficult for consumers to obtain effective evidence [2].

3.4 Platform Side: Systemic Risks of Responsibility Evasion and Lack of Supervision

As a rule, maker and data controller, the takeaway platform's behavior directly affects ecological health:

- Fuzzy responsibility: platforms transform labor relations into "cooperation" through agreements, avoiding the responsibility of social security and accident compensation for riders;
- Data hegemony: platforms control 85% of the traffic distribution, but the ranking algorithm is not transparent enough, and the standard deviation of order volume fluctuation of merchants reaches 40% [1];
- Regulatory vacuum: under the self-regulation model, platforms can adjust the percentage of commission at will (e.g., from 15% to 25%), while external regulation is lagging behind (the implementation rules of the E-Commerce Law have yet to cover algorithmic ethics).

4. Optimization Path: Tripartite Mutual Evaluation and Audit System Design

4.1 Three-Party Mutual Evaluation Audit System Design

In order to solve these problems, based on the technical optimization of the game model, this paper proposes a dynamic three-party mutual assessment audit system based on the theoretical framework of the Stackelberg game model and the three-party evolutionary game model [4,5,6] as shown in Figure 1, aiming to crack the information asymmetry and responsibility

ambiguity problems in the platform ecology through technological empowerment and institutional synergy.

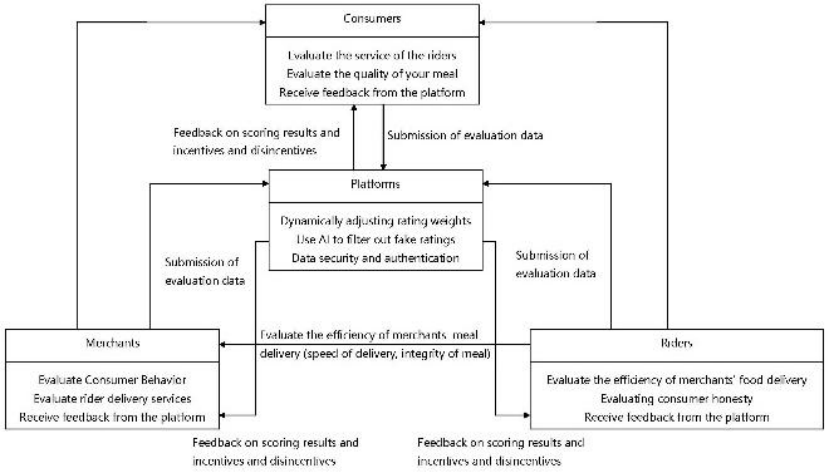

Figure 1. Dynamic Relationship of the Three-Party Mutual Evaluation and Audit System

4.1.1 System core mechanisms

a. Two-way scoring and dynamic weighting

Consumer-Rider-Merchant Mutual Evaluation: Consumers evaluate riders' service (e.g. punctuality, attitude), riders give feedback on merchants' delivery efficiency and meal quality, and merchants evaluate consumers' honesty (e.g. identification of malicious bad reviews).

Dynamic scoring algorithm: introduce the risk-sharing parameter (α) in the Stackelberg game, and the platform dynamically adjusts the weights of consumer scores according to the rider's accident rate. For example, when $\alpha \geq 0.6$ (the platform bears 60% of the risk cost), the impact of poor consumer ratings on the rider's income is reduced by 20%, alleviating the rider's speeding pressure. Table 1 demonstrates the allocation mechanism of dynamic scoring weights in the three-party mutual evaluation audit system:

Table 1. Distribution Mechanism of Dynamic Scoring Weights in the Three-Party Mutual Evaluation and Audit System

evaluation body	subject of evaluation	weighting of ratings(α=0.6)	weighting of ratings(α=0.8)
consumers	riders	40%	30%
riders	merchants	35%	40%
merchants	consumers	25%	30%

b. AI-enabled false evaluation filtering

The GPT-4 model is used to perform sentiment analysis and semantic recognition of evaluation text, combined with the compensation threshold theory in the evolutionary game, to automatically filter invalid complaints with a compensation amount lower than 15% of the order value, and enhance the credibility of the evaluation system.

4.1.2 Technology realization path

- Data security and trusted transmission:

Encrypt the evaluation data with SM4 home-grown cryptographic algorithm, and establish a secure transmission channel through IPSec VPN to prevent data tampering and leakage.

Build a tamper-proof evaluation deposit system based on blockchain technology to ensure that the scoring history is traceable and verifiable.

- VR scene simulation and training:

Utilize VR technology to simulate peak hour road conditions and bad weather scenarios to train riders in emergency handling. Pilot data shows that the accident rate of riders trained in VR decreased by 26%.

4.2 Existing Models and Case Studies

4.2.1 Application of the Stackelberg game model [4]

The risk-sharing contract model shows that when the platform bears more than 60% of the rider's transportation risk costs, the probability of the rider choosing a safe delivery speed is increased by 45%, and the delivery time set by the platform can be relaxed to $T = 2L/v_{safe} + 8$ minutes (L is the distance and v_{safe} is the safe speed). By piloting the model, Jingdong Takeout saw an 18% drop in rider overtime complaints, while consumer satisfaction increased by 12%.

4.2.2 Threshold design of three-party evolutionary game [7]

The study of overtime compensation mechanism points out that the system can converge to the ideal equilibrium (platform-initiated compensation, low-risk delivery by riders, and rational complaints by consumers) when the

compensation amount M ≥ 15% of the order value. After Meituan Takeout introduced the mechanism in 2022, the rate of rider traffic violations was reduced by 23%, and the rate of consumers' malicious bad reviews dropped to less than 5%.

4.2.3 Reward and punishment optimization of value co-creation model

Based on the value co-creation model of the evolutionary game [2], the platform rewards and punishments need to be controlled within the threshold range (medium level). For example, reward traffic tilt for high-quality merchants (exposure rate +20%), and implement downgrading penalties for brushing review merchants (ranking down 50%). By dynamically adjusting the rewards and punishments, HungryMall's merchant compliance rate increased by 35% and consumer repurchase rate increased by 18%.

5. Institutional Synergy Strategy

5.1 Policy Framework and Multi-Responsibility Co-Governance

5.1.1 Qualification Audit and Dynamic Public Announcement

According to the Food Safety Law and the Measures for the Supervision and Administration of Food Safety of Online Catering Services, takeaway platforms are required to establish a two-tier auditing mechanism:

- Online audit: automatically identify qualifications such as business licenses and food business permits through OCR technology, and compare them with the database of the General Administration of Market Supervision in real time [7];
- Offline verification: high-risk categories (such as fresh food, cold food) merchants to carry out on-site inspections to ensure that “ghost kitchen” zero tolerance. Jingdong Takeout's “Quality Dine-in Program” eliminated 12% of fake merchants through offline verification, significantly improving consumer trust.

5.1.2 Qualitative Policy Orientation

Implement a tiered management system to distribute traffic based on merchant compliance levels:

- Quality merchants: receive incentives such as homepage exposure weighting (+30%) and commission reduction (-5%);
- Non-compliant merchants: implement penalties such as downgrading (50% drop in ranking) and suspension of services. This move can reduce vicious competition and promote the transformation of the industry to quality first. Table 2 demonstrates the specific measures and effects of the merchant hierarchical management system.

5.2 Balancing Market Competition and Platform Regulation

5.2.1 Antitrust and Differentiated Competition

According to the Anti-Monopoly Law, platforms are prohibited from forcing merchants to “choose one or the other” and limiting the maximum commission (e.g., no more than 15%). By differentiating its positioning (focusing on “30-minute quality delivery”), Jingdong Takeaway avoids direct competition with Meituan and HungryMall, while attracting high-end merchants and increasing its market share by 8%.

Table 2. Specific Measures and Effects of The Merchant Hierarchy Management System

Merchant Level	incentives and punishments	Flow distribution adjustments	Commission Adjustment	Impact on the platform's ecology
Quality	Home page exposure weighting (+30%)	Flow tilt	Commission reduction (-5%)	Enhance consumer trust and increase orders
General	preserve the status quo	Regular allocation	No adjustment	Maintaining platform stability
Non-compliant	Downgrading (50% drop in rankings), suspension of services	Decreased flow	No adjustment	Reduce vicious competition and promote industry standardization

5.2.2 Transparent traffic distribution

Forcing platforms to disclose the logic of their ranking algorithms, for example, Meituan is required to disclose parameters such as “30% weighting of meal delivery speed and 25% weighting of rating” (draft revision of the E-Commerce Law), which reduces merchants' speculative behavior on traffic fluctuations. By disclosing the distribution rules of “100 billion subsidies”, the standard deviation of order volume fluctuation of merchants has been reduced from 40% to 18%.

5.3 Institutional Innovation for Consumer Protection

5.3.1 Price Transparency and Offer Compliance

- Dynamic price monitoring [8]: using AI to identify false promotions (e.g., “up first, then down”), and fining violating merchants 10% of sales (Article 55 of the Consumer Rights and

Interests Protection Law);
- Coupon underwriting traceability: recording the path of coupon issuance and usage based on blockchain technology, preventing the platform from tampering with the data. WeChat Takeaway has reduced its offer complaint rate by 22% through this technology.

5.3.2 Delivery Service Standardization

The implementation of the Code of Delivery Service for Takeaways requires platforms to provide more than two delivery methods (e.g., "Dada Second Delivery" and "Merchant Self-Delivery"), which consumers can choose on their own. The pilot of Jingdong Takeaway showed that the proportion of users choosing "delayed delivery" amounted to 35%, and the overrun rate of riders was reduced by 19%.

5.4 Synergistic Governance of Data Security and Algorithmic Ethics

5.4.1 Data sovereignty guarantee
- Encryption and desensitization: adopt SM4 algorithm to encrypt user track data, and dynamically desensitize sensitive information (e.g. residential address) [9];
- Blockchain Depository [10]: establishing an untamperable data audit chain to ensure that personalized recommendations meet the requirements of the Personal Information Protection Law. HungryMall has reduced data leakage incidents by 45% through this technology.

5.4.2 Regulation of Algorithm Transparency
- Third-party ethical review: commission an independent organization (e.g., the China Academy of Information and Communications Technology) to conduct an annual assessment of the platform's algorithms and identify discriminatory rules (e.g., downgrading of remote areas);
- Users' right to know: the platform is forced to display "reasons for recommendation", such as "because you often order Sichuan cuisine, we recommend similar merchants". After Meituan piloted this feature, user complaints about the recommendation results dropped by 30%.

5.5 Rider Rights and Interests and Institutional Design of Green Delivery

5.5.1 Labor Rights and Interests Protection
- Risk sharing contract: refer to the Stackelberg game model, require the platform to bear 60% of the cost of riders' traffic insurance, and include it in the Guidelines for the Protection of Labor Rights and Interests in New Employment Patterns;
- Income protection mechanism: set up a bad weather subsidy (e.g., +$2 per order on rainy and snowy days) and guaranteed income during peak periods (e.g., $30 per hour) to reduce income fluctuations.

5.5.2 Green Distribution System
- Mandatory standards for environmentally friendly packaging: According to the "Opinions on Further Strengthening the Control of Plastic Pollution", merchants are required to use ≥50% of biodegradable packaging, and violators are fined 3% of sales;
- Carbon point rewards: consumers who choose "tableware-free delivery" can get points to exchange for coupons, with a participation rate of 42% in the pilot cities.

5.6 Dynamic Regulation and Cross-Platform Synergy

5.6.1 Regionalized Policy Adaptation
- Differentiated regulation: first-tier cities focus on regulating the compliance of delivery vehicles (e.g., electric vehicle licenses), while third- and fourth-tier cities focus on food safety spot checks;
- Pilot experience promotion: WeChat's "Store Express Delivery" model of no-touch delivery and rider health punch card piloted in Beijing can be replicated in high-risk areas across the country.

5.6.2 Cross-platform Data Interoperability

Under the premise of privacy protection, promote the sharing of merchant credit data among platforms such as Meituan and HungryMall, and establish industry-level blacklists. For example, if a merchant is penalized for brushing orders at Meituan, its credit score at HungryMall is automatically adjusted downward by 20%.

6. Conclusion and Prospect

This paper reveals the dynamic game relationship among consumers, merchants and riders in the takeaway platform through Stackelberg game and three-party evolutionary game model, and proposes the dual-path governance framework of "technical empowerment - institutional synergy". The study finds that technical empowerment (e.g., AI false review identification, blockchain data depository) can significantly crack information asymmetry and enhance the credibility of the evaluation

system; institutional synergy (e.g., risk-sharing mechanism, design of overtime compensation thresholds) can clarify the boundary of responsibility and promote the convergence of the three-party strategy to the ideal equilibrium. The pilot of Jingdong Takeout shows that when the platform bears more than 60% of the cost of rider transportation risk, the rider accident rate drops by 26%, and the consumer complaint rate decreases by 18%, which verifies the effectiveness of dual-path synergy.

Future research needs to focus on the interpretability standards of algorithmic ethics and cross-platform collaborative governance networks. On the one hand, AI decision-making transparency rules should be established to force platforms to disclose algorithmic logic and pass third-party audits and certifications, so as to avoid technological black boxes; on the other hand, blockchain-driven industry-level data sharing platforms can be explored to realize cross-platform interoperability of merchants' credit scores and riders' service records, so as to build a deterrent mechanism of "one place violates the law, and restrictions are imposed everywhere". Deterrent mechanism. In addition, policymaking needs to be dynamically adapted to technological development, such as piloting an "algorithmic sandbox" in North, Shanghai, Guangzhou and Shenzhen, allowing platforms to test new modes of delivery such as drone delivery within the regulatory framework, and then expanding the program nationwide after accumulating experience.

In short, the essence of the tripartite game of the takeaway platform is the conflict between the logic of technology and the logic of the system. The only way to build a sustainable platform ecology is to integrate algorithm transparency, data security and responsibility clarity, which will provide theoretical support and practical paradigm for the reconstruction of labor-management relations in the era of digital economy.

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