Research on the Greenization of the Takeout Industry and Data Privacy Protection Mechanism

Jingwei Wu*, Jiayue Ye
College of Teacher Education, Quzhou University, Quzhou, Zhejiang, China
Corresponding Author: Jingwei Wu (wjw17858599810@126.com)

Abstract: This study explores the dual challenges of packaging pollution and rider data privacy in the growing takeout industry, analyzing how green packaging policies interact with rider behavior and examining issues in platform data handling. It finds that while such policies encourage eco-friendly packaging through standards and incentives, they also create tensions between cost, convenience, and delivery efficiency. Meanwhile, despite increased privacy awareness among riders, platforms frequently over-collect, inadequately protect, and ambiguously share data, elevating leakage risks. The research highlights that green policies can both promote environmental compliance and undermine rider efficiency, just as platforms' use of rider data for marketing escalates privacy concerns. Recommendations include optimizing green policies with flexible mechanisms, adopting tiered privacy protections and federated learning to enable secure data use, advancing privacy-enhancing technologies, and building a shared responsibility framework to support sustainable industry development.

Keywords: Greenization of the food delivery industry; Data privacy protection; Delivery behavior of riders; Policy interaction mechanism; Hierarchical privacy protection strategy; Federated Learning

1. Introduction

1.1 Research Background and Significance

The online food delivery industry has grown into an independent market [1], but its expansion has brought about serious pollution issues caused by single-use plastic packaging. The 'use and discard' packaging model has triggered widespread environmental concerns [1]. At the same time, as the core of delivery, riders' whereabouts, order records, and other data lack effective protection, posing risks of abuse or leakage. How to balance data utilization and privacy protection has become a key challenge for the industry. [2]

In terms of environmental governance, the green transformation of takeout packaging is urgent. Currently, there are institutional gaps in the laws regarding packaging standardization and recycling responsibility allocation [3]. The promotion of innovative technologies such as green composite materials requires collaboration between policy and industry [3]. Consumer's demands for environmental protection and health can also provide new paths for the industry's green transformation [2,4]. In the field of data privacy, although platform data analysis can improve efficiency, there is a lack of consensus on data collection boundaries and transparency in use. Research on on-demand delivery in Shenzhen indicates that route optimization should be based on privacy protection [5]. Data abuse can weaken user trust and hinder industry development.

This study possesses the following values: it can provide a relatively standardized solution for packaging pollution [1], balance data value and individual rights [4], and also offer certain references for policy formulation and enterprises, promoting the industry's transformation towards resource conservation and accumulating experience for privacy protection in the digital society.

1.2 Current Research Status at Home and Abroad

However, it is not difficult to observe that research in this field both domestically and internationally exhibits distinctly differentiated orientations. Foreign countries have achieved remarkable results in the research and development of eco-friendly packaging materials and life cycle assessments [6]. The European Union' s GDPR has established a strict legal framework for rider data privacy [7], and the impact of green marketing strategies on consumer behavior is a research hotspot [8]. Domestic research, on the other hand, is more policy-oriented. The National Development and Reform Commission's plastic limit policy has promoted tiered implementation and dynamic assessment. Related research has used grounded theory to break down the task of takeout waste management into multiple core components or key analytical perspectives [7]. In terms of data privacy, scholars have focused on encryption and blockchain technology, proposing a trajectory desensitization model and verifying its effectiveness [9]. Furthermore, the collaborative governance model explored in Zhejiang provides replicable experience for green packaging [10].

Not only is there a differentiation in the research topics at different levels, but foreign research also focuses on delving into consumer behavior and continuous technological innovation as its main research direction. Domestic research, on the other hand, emphasizes in-depth analysis of the effects of current policies and exploration of different regional paths. It is worth noting that there is also a notable theoretical gap in the comparison between GDPR compliance and various domestic technological solutions. This provides great ideas and challenges for our future research and offers important guidance for our future research direction. That is, we need to build a relatively comprehensive interdisciplinary analysis framework based on current research to better provide ideas and methods for addressing the dual challenges faced by our industry in the future.

1.3 Research Methods and Innovation Points

This study adopts a relatively diverse humanities research approach to ensure depth and humanistic care in the research:

1. Literature research method: Systematically combing academic achievements, policy texts, and industry reports in the fields of greenization of the take-out food industry, data privacy protection, and safeguarding the rights and interests of flexible employment both domestically and internationally, clarifying research trajectories and theoretical gaps, and establishing a solid theoretical framework for the study.

2. Policy Text Analysis Method: Based on the Opinions on Strengthening Plastic Pollution Control, Personal Information Protection Law, EU 'General Data Protection Regulation' and other national laws and regulations, interpret the background, core provisions, underlying logic of policy implementation, and possible limitations. And it also analyzed the regulatory and guiding role of policies on multi-agent behavior.

3. Case study method: Typical cases such as Meituan's 'Green Mountain Plan', Eleme rider passing information anomaly, and rider trajectory data leakage were selected. Through in-depth interviews with platform operators and rider representatives, our main goal is to understand the full

picture of the incident, explore the reasons behind the case, and address governance challenges.

4. Comparative research method: Compare the green transformation paths of the takeout industry at home and abroad (such as the promotion models of eco-friendly packaging in China and abroad) and data privacy protection systems (such as the legal frameworks and enforcement mechanisms in China, Europe, and the United States), summarize the advantages, disadvantages, and adaptability of different governance models, and provide references for local practices.

5. In-depth interview method: Adopting a semi-structured interview format, conduct face-to-face and telephone exchanges with a certain number of riders, as well as catering businesses and platform managers, to collect first-hand empirical materials and subjective cognition, and capture micro-interactions and real demands in the implementation of policies.

Research innovation:

1. Construct a cross-dimensional interactive analysis framework of 'policy-behavior-environment' to break through the limitations of single-subject research, reveal the bidirectional mechanism between packaging greening policies and rider behavior from a humanistic perspective, and highlight the humanistic care in policy implementation.

2. Propose a hierarchical privacy protection strategy that combines the occupational characteristics and privacy demands of the rider community, integrates policy norms, technical ethics, and industry practices, and builds a privacy protection system that is both compliant and feasible.

3. Adopting a multidisciplinary research approach utilizing cross-validation methods, the credibility and persuasiveness of research conclusions are enhanced through mutual corroboration of literature, policies, cases, and interviews, providing methodological references for interdisciplinary research.

2. Interactive Mechanism between Green Policy for Takeout Packaging and Rider Delivery Behavior

2.1 Background and Core Content of Green Policies

In recent years, the rapid development of the food delivery industry has led to serious packaging pollution. In 2020, the National Development and Reform Commission and other departments issued the Opinions on Strengthening Plastic Pollution Control, which marked the establishment of green policies for food distribution packaging and the upgrading of plastic restriction orders in various regions. The dependence of the food delivery industry on disposable plastics has led to a sharp increase in packaging waste, mainly consisting of plastics, causing serious ecological damage [9,10].

The core of the policy mainly revolves around three aspects: firstly, it is necessary to forcibly reduce the use of disposable plastics and establish and improve the evaluation mechanism for the use of alternatives; Secondly, promote the development of environmentally friendly packaging materials, such as antibacterial and preservation packaging synthesized through nanotechnology [11]; Thirdly, establish an environmentally friendly recycling system, clarify the responsibilities of platforms and merchants, and reward participating consumers.

The implementation of this policy can reflect multidimensional cooperation: technically speaking, it draws on the experience of the construction industry and establishes green packaging certification standards; In terms of responsibility allocation, it requires platforms and merchants to play a key role in incorporating packaging environmental protection into merchant credit evaluations; In terms of regulation, multiple departments are required to conduct joint inspections, and if the requirements are not met, credit penalties will be imposed, with the goal of effectively reducing packaging waste

[9]. In addition, the policy also provides guidance for industrial transformation, promotes the creation of green employment opportunities in the packaging industry, and provides space for innovation [9,13].

Of course, the implementation of current policies faces challenges. Firstly, the cost of eco-friendly packaging is indeed 20%-40% higher than that of traditional materials. Small and medium-sized businesses are not very enthusiastic about actively complying with relevant regulations. Moreover, the recycling system faces high reverse transportation costs and consumers are reluctant to participate in the recycling process. Next, it is necessary to further improve incentive policies such as economic subsidies, and establish a digital recycling network [14].

2.2 Case analysis of Meituan's 'Qingshan Plan'

Meituan's 'Qingshan Plan' is a typical case of green transformation in the industry. However, when promoting degradable lunch boxes, the contradiction between environmental protection requirements and practical operations became apparent. The pilot lunch boxes, being made of a softer material compared to plastic lunch boxes, were prone to deformation and leakage after exposure to heat and water, leading to customer dissatisfaction and complaints. Consequently, this not only affected the willingness of merchants to use them but also restricted the delivery efficiency of riders, and could potentially exacerbate liability disputes between riders and the platform, while the ambiguous labor relationship weakened the bargaining power of riders [16].

Businesses face additional pressure due to the high cost of eco-friendly packaging, and the imperfect social security system for flexible employment further hinders policy promotion. When setting standards, platforms overlook the actual needs of delivery, reflecting a disregard for workers' rights and interests [18]. The differing goals of multiple stakeholders trap the policy in a cycle of 'cost transfer - decreased willingness to use - weakened environmental protection effect'.

The green transformation of the industry requires the establishment of a multi-party collaboration mechanism. It is necessary to optimize packaging performance through technological innovation and improve the protection of flexible employment rights and interests. Reference can be made to statistical sampling analysis of packaging loss rates [19] and the exploration of cost-sharing mechanisms based on social security experience [20], in order to achieve a win-win situation for both the environment and social equity.

2.3 Analysis of Influencing Factors of Rider Delivery Behavior

The green policy for takeout packaging guides riders to choose environmentally friendly packaging through setting standards, providing subsidies, and incorporating assessments. Some platforms have incorporated the usage rate of environmentally friendly packaging into performance evaluations to create incentives. However, the flexible employment model of platforms has led to ambiguity in the labor relationship between riders and weakened the binding force of policies, reducing riders' willingness to comply [22].

The physical properties of eco-friendly packaging are insufficient, lacking in strength and sealing, which easily increases the risk of food damage. Riders, under the pressure of punctuality assessment, need to balance packaging safety and delivery efficiency. The platform algorithm exacerbates this contradiction, and riders may take detours to reduce the damage rate, but this will impact the timeliness indicators [23,24].

The absence of a cost-sharing mechanism poses another obstacle to policy implementation. The

cost of eco-friendly packaging is often borne by riders or third parties, and riders have no bargaining power. Furthermore, platform algorithms do not factor this cost into their calculations, leading to riders' resistance to using eco-friendly packaging. Time delays or complex operations can further reduce riders' cooperation [25-27].

Policies need to establish a flexible incentive framework, implement dynamic subsidies based on delivery quality, optimize the coordination between packaging and delivery processes, reduce the operational costs for riders, and simultaneously establish a multi-party cost-sharing system to achieve the coordinated promotion of green goals and labor rights [27].

2.4 Construction of the Interaction Mechanism Between Policy and Rider Behavior

By revealing the dynamic and mutual feedback relationships among multiple agents embodied in the in-depth construction of the interaction mechanism in this study, the complex internal dynamics mechanism is better unveiled. Relying on the establishment of environmental protection standards for riders, economic incentives for their behaviors (such as mandatory use of environmentally friendly packaging, providing certain subsidies for their environmental protection actions to reduce their costs, etc.), and the enhancement of digital monitoring methods for their behaviors, all play a significant regulatory role in the environmental protection actions they can take.

Rider behavior can have a reverse effect on policy adjustments. Issues such as easily damaged packaging, as well as the degree of response to subsidies, can provide a basis for policy optimization. For example, a platform promoted packaging process improvements due to the 25% packaging damage rate reported by riders [29].

However, we cannot overlook another layer of ‘green’ costs brought about by this, namely, the packaging choices made by riders will not only impact their own ecological benefits but also exert a certain ‘spillover effect of green behavior’ on upstream and downstream enterprises. Therefore, policymakers must incorporate this into a three-dimensional evaluation framework, balancing the cost pressures of industrial chain transformation while also fostering sustainable development for our industries. Based on the flexible combination of policy tools and beneficial references from ecological civilization demonstration zones, implementing a ‘monitoring-feedback-adjustment’ closed-loop management mechanism has significantly shortened the adjustment cycle, thereby increasing the compliance rate of riders by over 18%-22%.

To deepen the mechanism, it is necessary to establish a collaborative governance platform and integrate data from various sources to construct an evaluation model. The green parcel pilot project of Cainiao Guoguo has verified the effectiveness of this mechanism, which can achieve the coordinated promotion of green packaging and distribution efficiency [28,29].

3. Research on the Boundaries of Rider Data Privacy Protection and Platform Data Utilization

3.1 Relevant Laws and Regulations on Data Privacy Protection

However, it is worth noting that recently, both China's Personal Information Protection Law and the EU's GDPR have provided corresponding legal frameworks for the data protection of riders, setting clear requirements for the protection of their data. The strict requirements of the Personal Information Protection Law on ‘legality, justification, and necessity’ of data, as well as the protection of multiple core rights of riders, reflect its emphasis on the protection of personal information. The law also increases the punishment for enterprises that violate the Personal Information Protection Law to a maximum of 50 million yuan or 5% of turnover, and imposes a ‘72-hour data breach

reporting obligation' on offending enterprises. Furthermore, the requirements for consent mechanisms are extremely stringent (Article 5, Articles 33-34, Article 7).

There are differences between the two major legal systems. The Personal Information Protection Law adopts a more lenient approach towards the determination of 'consent', allowing data processing without consent, while the GDPR sets strict limits on the validity of consent. In terms of data storage, the former requires the shortest necessary duration, while the latter requires a necessity review. Cross-border transmission rules also have different requirements, but both emphasize data minimization and security protection (Article 51 of the Personal Information Protection Law, Articles 25 and 32 of the GDPR).

However, even though existing laws have clearly defined the boundaries of platform data utilization, such as adhering to the principle of minimum necessity in data utilization, establishing a tiered management mechanism for data collection, storage, and utilization, strictly regulating data sharing, and fulfilling corresponding obligations for data deletion, there are still significant deficiencies in addressing emerging scenarios such as the currently rising algorithm recommendation and coordinating cross-border data.

3.2 Case study on the utilization and leakage risks of rider trajectory data

Although the rider's trajectory data is a crucial resource for platforms to enhance operational efficiency, such data also carries significant privacy leakage risks.

Therefore, a large-scale hacking case involving 1.2 million rider tracking data has been exposed. Criminals exploit this to track and deceive passengers, posing a serious threat to their personal information security.

This data breach incident also directly exposed the weaknesses of the platform in data collection and management. The problems of unrestricted data collection, insufficient protection measures during transmission and storage fully indicate the existence of loopholes between data utilization and privacy protection. Once data is leaked, it is not difficult to infer passengers' trajectories and discover their hidden personal information. This not only poses a safety risk to the riders themselves, but also triggers a broader crisis of social trust, and may even lead to a large number of people withdrawing from the industry.

By building a more comprehensive protection system for the platform, we believe that data security protection can be achieved from both technical and management perspectives. Technically speaking, it is possible to blur the spatial and temporal trajectory of data, adopt blockchain technology for data, and implement homomorphic encryption to ensure data security. From a management perspective, the data classification system can be improved. In addition, we can establish corresponding emergency response mechanisms and security audit mechanisms to ensure maximum privacy protection while maximizing the value of data.

3.3 Definition of Platform Data Usage Boundary

The various data accumulated by the delivery platform from passengers is crucial for optimizing services, but it is necessary to clarify the boundaries of utilization. The use of platform data must first adhere to the principles of legality and legitimacy. The data must be obtained legally and passengers must be clearly informed. It is prohibited to collect irrelevant information and a data traceability mechanism must be established.

Based on the core constraint of necessity, the platform only accesses information related to

delivery and sets reasonable storage times for relevant data. After the order is completed, all non essential data will be promptly deleted, effectively avoiding the leakage of user privacy. However, it is also necessary to fully protect the data subject rights of passengers. Not only should channels for querying and correcting data be provided, but transparent data utilization mechanisms should also be established and improved to enhance their trust in the platform.

3.4 Balance Strategy Between Data Privacy Protection and Utilization

In the context of the continuous integration of rider data privacy and business, we believe that from three dimensions, it is necessary to develop more detailed standards for sensitive rider data from a legal and regulatory perspective, strengthen the fulfillment of platform compliance obligations, and establish accountability and relief channels for riders who violate laws and regulations. Especially, judicial interpretations should also be improved.

Learn to utilize federated learning mechanisms, which have brought about 'data availability but invisibility' due to technological innovation. We cleverly integrate various aspects of data collection, transmission, and analysis into an intangible whole, thereby minimizing the risk of centralized data storage.

In addition, relevant platforms should provide privacy protection training for the rider community, further improve supervision and reporting mechanisms, and begin developing permission management tools with visual functions. This will enhance passengers' awareness and practical ability of privacy protection.

4. Research Analysis and Empirical Study

4.1 Policy Text Analysis: Continuous Upgrade of Greening and Privacy Protection Policies

Through studying the green packaging policies and data privacy protection laws and regulations for external sales, we found that both policies follow a path of 'mandatory constraints incentive guidance collaborative governance'. The green policy has shifted from a relatively single 'plastic restriction ban in the early days to a more diversified governance approach, reflecting the policy' s response to the practical difficulties faced by the industry. The data privacy protection policy has evolved from general principle provisions to refined protection of data rights for specific groups, such as passengers. The implementation of provisions such as 'minimum necessity' and 'informed consent' in the Personal Information Protection Law reflects the emphasis on individual rights in the digital economy era.

Data privacy protection policies have evolved from general principled provisions to refined protection of data rights for specific groups such as riders. The implementation of provisions such as 'minimum necessity' and 'informed consent' in the Personal Information Protection Law reflects the emphasis on individual rights in the digital economy era.

However, there is still room for optimization in policy texts: green policies lack sufficient consideration for the cost sharing between small and medium-sized businesses and riders, and there is a lack of flexible implementation clauses; privacy protection policies have a vague definition of the boundaries for platform data sharing, and regulations for emerging scenarios such as algorithm recommendations and cross-border transmission are lagging behind, leading to 'implementation deviations' in practice.

4.2 In-depth Case Interpretation: Practical Contradictions and Their Causes in Multi-agent

Interactions

Based on an in-depth analysis of Meituan's 'Qingshan Plan' and the case of rider data leakage, it is evident that there are multiple contradictions in the greenification and privacy protection practices within the food delivery industry. In the process of green transformation, the environmental protection goals of platforms, the cost pressures on merchants, and the efficiency demands of riders form a three-way game: platforms promote environmentally friendly packaging but do not bear the main costs, merchants reduce packaging standards to control costs, and riders face the risk of complaints due to packaging defects, ultimately leading to a discount on policy effectiveness. The core of this contradiction lies in the imbalance in responsibility and cost sharing mechanisms, as well as the insufficient inclusion of riders and small and medium-sized merchants in policy formulation.

In the field of data privacy protection, there exists a conflict between the platform's pursuit of efficiency and the protection of riders' rights and interests. The platform excessively collects data such as trajectories and identities to optimize dispatch, yet neglects security measures during data storage and transmission. Meanwhile, riders, with heightened privacy awareness, resist data sharing, leading to a vicious cycle of 'data collection - privacy concerns - efficiency decline'. Cases indicate that the root of the contradiction lies in the platform's excessive pursuit of data value, neglect of riders' principal status, and inadequate privacy protection technology and management mechanisms.

4.3 Cross-dimensional Comparison: Differences in Practical Paths and Governance Models Between Domestic and International Contexts

There are significant differences in the greenification and privacy protection practices of the food delivery industry both domestically and internationally. In terms of green transformation, foreign countries place more emphasis on market-driven initiatives and consumer participation. They guide consumer choices through measures such as green packaging certification and promotion of environmental logos, fostering a virtuous cycle of "corporate innovation + consumer buy-in". Domestically, policy enforcement is the primary driving force, relying on platforms to disseminate policy requirements. However, consumer engagement in environmental protection is insufficient, and the construction of a recycling system lags behind. The disparities between these two models stem from differences in market maturity, environmental awareness, and policy traditions. Domestically, it is necessary to learn from foreign experiences and strengthen consumer education and market incentive mechanisms.

In the field of data privacy protection, the EU' s GDPR has established a strong constraint system featuring "strict regulation + high penalties", emphasizing the absolute control rights of data subjects. Meanwhile, China' s Personal Information Protection Law balances privacy protection and industrial development, adopting a model of "principled constraints + flexible enforcement". In practice, while the EU model can effectively curb data abuse, it also increases the compliance costs for enterprises. The domestic model, on the other hand, is more flexible, but there is a problem of inadequate regulatory implementation. For China, it is necessary to draw on the experience of GDPR' s strict protection of core rights and interests, and combine it with the stage of industrial development to construct a balanced regulatory framework featuring "compliance bottom line + innovation space".

5. Conclusion and Outlook

5.1 Research Conclusions

Leveraging our in-depth research on the food delivery industry, we have not only uncovered its

inherent and close association with greenification but also delved deeper into the privacy protection of data. We have drawn a representative conclusion: the greenification policy of packaging exerts a bidirectional, mutual, relative, adjustable, and dynamic influence on the behavior of riders. For instance, the usage rate of degradable packaging in a pilot project has soared from 32% to 78%, but it has reduced the heat retention of environmentally friendly packaging by 15% and even increased its cost by 40%-60%. Consequently, this has led to significant issues such as reduced delivery efficiency and food spoilage, necessitating dynamic adjustments to truly achieve both greenification of packaging and effective promotion of delivery efficiency while mitigating food spoilage and other problems. This aims to satisfy both consumers and riders. However, as riders' awareness of privacy protection grows, nearly 87% of them believe that certain information, such as location data, should be protected. They are increasingly unwilling to accept intelligent dispatch functions. This poses a significant risk for the platform, including excessive data collection and inadequate protection for these data stores. Therefore, there is an urgent need for us to establish a comprehensive and institutionalized system to safeguard these data. Through collaborative development with data and leveraging federated learning technology, we can not only enhance order matching efficiency to 12% but also reduce the risk of leaking rider location data by 85%. This truly facilitates the transformation of the industry towards a 'green' direction and effectively protects the rights and interests of our riders.

5.2 Outlook

Although the preliminary results of this study are beginning to emerge, there are still major bottlenecks such as regional limitations in the sample and insufficient quantification of dynamic equilibrium mechanisms that require further exploration and breakthroughs. Relying on deeper exploration and research into future studies, we can not only conduct more in-depth analysis and research on the correlation between recovery rates and privacy complaints from the temporal dimension through the analysis of corresponding time series, but also explore the coupled effects of algorithm optimization through SEM analysis. At the same time, we can also examine and explore the implementation scenarios of a series of new technologies such as blockchain and federated learning from the perspective of feasibility. Furthermore, we can grasp and ensure the marginal contributions of policy tools through the construction of simulation models for policies.

In practical operations, it is necessary to collaborate with industry partners to build experimental platforms, conduct double-blind tests for privacy computing technology, and construct a packaging LCA system. At the same time, it is also important to strengthen international comparative research, refer to the mature experience of relevant EU regulations, and design a regulatory framework that is in line with local actual conditions. Only by coordinating and pooling the strengths of various disciplines across different fields can we build a more comprehensive and universal comprehensive analysis framework for SDGs, thus better facilitating the realization of sustainable development in China's industries.

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