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Research article

Aligning freight services and vehicle sales: Strategic cooperation for new energy commercial vehicle adoption

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Abstract: Promoting new energy commercial vehicle (NECV) adoption in freight transportation remains challenging, as a sluggish freight market dampens logistics service providers' (LSPs) willingness to invest and exacerbates overcapacity pressure on manufacturers. While online freight platforms (OFPs) can enhance vehicle utilization and stimulate demand, how manufacturers and platforms should cooperate to effectively promote NECVs remains unclear. This study developed a stylized game-theoretic supply chain model comprising a manufacturer, an OFP, and LSPs to examine strategic sales cooperation. We analyzed three settings—no cooperation, agency cooperation, and reselling cooperation—under manufacturer-led and platform-led power structures. The results showed that cooperation does not universally improve outcomes. The manufacturer generally prefers the reselling mode, whereas the OFP's preference depends on competitive intensity and unit freight service revenue, potentially leading to a prisoner's dilemma. Compared with the agency mode, the reselling mode better aligns incentives and can enhance market expansion but may intensify channel competition. Moreover, power structure plays a critical role: when the platform controls sufficient freight demand, a platform-led structure more effectively incentivizes service improvement and market expansion; otherwise, a manufacturer-led structure helps restrain opportunistic platform behavior. From an environmental perspective, although reselling improves utilization-phase benefits, it does not necessarily enhance lifecycle sustainability unless production-phase emissions are substantially

reduced. These insights provide strategic guidance for promoting NECVs and integrating freight and vehicle sales.

Keywords: NECV adoption; online freight platform; sales modes; cooperation and competition; game theory
Mathematics Subject Classification: 91-10, 91A10

1. Introduction

The road freight sector contributes over 60% of total transport emissions, making freight decarbonization an urgent priority [1]. Promoting the adoption of new energy commercial vehicles (NECVs) is widely recognized as a key pathway toward reducing emissions in freight transportation. In response, both incumbent manufacturers (e.g., Volvo and Daimler) and new entrants (e.g., Deepway) have substantially increased investments in NECV development, leading to a rapidly expanding supply base [2].

Despite this momentum on the supply side, NECV adoption in the freight sector remains well below expectations [3]. In practice, several barriers continue to hinder large-scale adoption, including limited driving range, inadequate charging infrastructure, long charging times, and the relatively high purchase cost of NECVs. In addition, unlike private consumers in passenger vehicle markets, logistics service providers (LSPs) make vehicle purchase decisions primarily based on operational profitability and economic viability. Fragmented freight demand, high empty mileage, and mismatched capacity further undermine expected returns from NECVs, weakening LSPs' incentives to adopt or replace vehicles [4]. This mismatch between a thriving supply and cautious demand has created overcapacity issues for manufacturers. For example, Tesla's Cybertruck has seen significant stockpiling at its Texas Gigafactory, prompting steep discounting [5]. Meanwhile, market concentration in the NECV sector has intensified: in 2023, the top 10 manufacturers captured 72.1% of China's NECV market share [6], reflecting escalating competitive pressure [7]. These challenges highlight the urgency of accelerating NECV adoption, not only to achieve environmental targets but also to alleviate manufacturers' profitability challenges.

Online freight platforms (OFPs) have emerged as a promising channel for stimulating NECV adoption. By aggregating fragmented freight demand and improving the relationship between shippers and LSPs, OFPs reduce idle time and increase capacity utilization [8,9]. Survey data from platforms such as Yunmanman and Shengsheng Freight show that nearly 50% of LSPs reported reduced idle time after joining such platforms [10]. For NECV manufacturers, higher utilization directly improves returns for LSPs, and platforms also provide manufacturers with broader product exposure and branding opportunities that traditional dealership channels cannot match, thereby offering a novel pathway for promoting NECV sales [11]. In other words, freight demand and NECV sales exhibit a mutually reinforcing, synergistic relationship.

Recognizing cross-market synergies, NECV manufacturers are increasingly engaging in sales cooperation with OFPs. Two dominant cooperation models have emerged. Under the agency model, manufacturers retain ownership and pricing authority over vehicles, while OFPs provide promotional exposure and access to potential buyers. This arrangement limits channel conflict but may weaken the alignment between sales decisions and platform-side service investments. For instance, Shengsheng

Freight provides NECV manufacturers with advertising channels to reach potential buyers. In contrast, the reselling model allows OFPs to purchase vehicles from manufacturers and resell them to LSPs, which strengthens platform incentives to promote vehicle adoption but introduces risks of price competition and margin erosion. Lalamove exemplifies a platform providing an NECV sales channel. While such trade-offs have been extensively examined in traditional retail contexts [12,13], their implications cannot be directly applied to the context of OFPs. This is due to the platform's dual role as both a vehicle distributor and a freight service intermediary, which creates unique interdependencies between sales and operational performance not present in traditional retail channels.

Furthermore, interactions between vehicle sales and freight service introduce additional strategic tensions. On the one hand, increased vehicle adoption expands the platform's operational scale, generating higher revenue and network effects, but it may also lead to congestion in freight matching when the platform's capacity is constrained [14]. Congestion inevitably drives up operational costs, manifested as prolonged order waiting times, elevated idle vehicle hours, and additional human resources and algorithmic investment for order dispatching and coordination, which in turn weakens the platform's willingness to further promote NECV sales. For instance, survey data collected from a leading freight platform in Q3 2023 shows that as onboard vehicle capacity expanded, the average order waiting time for LSPs increased from 28 to 47 minutes, clearly suppressing the platform's marginal incentive for sales promotion. On the other hand, the evolving power structure further complicates outcomes under reselling. As OFPs gain bargaining power, such as Full Truck Alliance, manufacturers risk channel encroachments intuitively [15,16]. Meanwhile, stronger platform dominance may induce increased investment in matching technologies, generating positive spillover effects that enhance platform attractiveness. Thus, whether platform-led cooperation ultimately improves or undermines system performance remains theoretically ambiguous. Reflecting these trade-offs, manufacturers have adopted divergent strategies in practice; some, such as Shineray Auto, collaborate closely with major OFPs like Lalamove, whereas others, such as FAW Jiefang, have established proprietary platforms (e.g., "UNID") to reduce platform dependence. These contrasting approaches underscore the need for a systematic analysis of how platform capabilities, channel configurations, and power structures jointly shape cooperation outcomes.

Although collaborative sales practices are increasingly common in freight markets, they remain underexplored in the academic literature. Existing studies largely focus on two well-established platform types. Research on B2C retail platforms primarily emphasizes their role as transactional intermediaries [17,18], while studies on C2C sharing platforms—such as mobility platforms—highlight improvements in utilization efficiency [19,20]. Most of this work examines a single market or functional dimension, such as the choice of cooperation modes [21] or the value creation of sharing services [22]. In contrast, OFPs simultaneously perform dual functions in practice. They serve not only as sales channels that facilitate vehicle promotion but also as operational infrastructures that enhance the profitability of LSPs. This dual-role setting gives rise to a two-dimensional value creation mechanism, in which sales and service activities reinforce each other. However, such interactions have not been systematically incorporated into existing theoretical frameworks. Although Sun et al. [23] analyzed the role of platforms in promoting NECVs, they did not fully capture the platform's dual role as both a marketing intermediary and a demand aggregator, and paid limited attention to cross-market complementarities and channel coopetition arising from this dual functionality. To address these gaps, this study investigates the strategic choice and performance implications of NECV sales cooperation modes in freight markets. Specifically, we seek to answer the following research questions:

(1) Can cooperation with OFP effectively promote NECV adoption? And in turn, how does such cooperation influence freight-side decisions such as investments in matching capability?

(2) Which cooperation model yields superior performance? And do the manufacturer and the OFP have aligned strategy preferences?

(3) How does the power structure, namely, manufacturer-led and platform-led, influence the equilibrium cooperation choice? Can a greater market penetration and profitability be achieved under a manufacturer-led scenario?

To this end, we develop a game-theoretic model involving an NECV manufacturer, an OFP, and a continuum of freight service providers. The manufacturer may choose between agency and reselling cooperation, while LSPs base vehicle purchase decisions on anticipated freight returns. We examine the equilibrium outcomes under both models and assess how bargaining power and platform capabilities shape decisions. Our main findings are as follows:

First, we identify a demand-pull mechanism: improvements in platform freight profitability and resource availability increase expected returns for LSPs and thereby stimulate NECV demand. However, cooperation between the manufacturer and the OFP does not universally improve market outcomes. Under the agency model, a free-riding problem may arise: because the OFP benefits from revenue sharing on vehicle sales without directly bearing inventory risk, it may adopt a low-cost strategy and underinvest in matching capabilities, which can ultimately suppress freight efficiency and even reduce vehicle demand. This distortion is particularly pronounced when the OFP possesses strong market expansion capability, as generous revenue sharing allows the platform to extract profits that are weakly linked to actual increases in vehicle adoption.

Under the reselling model, freight supply conditions and unit freight revenue fundamentally reshape platform behavior. The OFP endogenously coordinates its resale markup with investments in matching capability. When freight supply is sufficient, the OFP adopts a service-oriented strategy, characterized by higher investment in matching technologies. In contrast, under constrained freight supply, the OFP relies more heavily on price reductions to enhance channel attractiveness. Platform capability further moderates demand interactions across channels. When freight availability is limited, greater acceptance of the reselling channel induces the OFP to strengthen service investment while adjusting prices to expand adoption. However, under an abundant freight supply, increased reliance on the reselling channel may intensify channel competition, leading to demand erosion in the traditional channel. Despite these tensions, the integration of freight services and vehicle sales mitigates double marginalization, and strong platform market-expansion capability can offset potential cannibalization, thereby increasing total market demand.

Second, from a profit-maximization perspective, the OFP consistently benefits from cooperation by gaining an additional revenue stream. In contrast, the manufacturer exhibits more nuanced preferences. Contrary to conventional wisdom, the manufacturer does not necessarily benefit from partnering with the most capable platforms. Excessive platform expansion capability amplifies free-riding incentives under the agency model and intensifies price-based competition under the reselling model, both of which erode manufacturer margins.

Moreover, compared to the agency model, the reselling model offers better strategic alignment between the OFP and the manufacturer, as both parties share incentives to promote vehicle sales. This alignment enhances market penetration and improves the manufacturer's profit potential. However, when the OFP has strong market expansion capability but limited freight supply, reselling cooperation may lead to lower investment in matching technologies than agency cooperation, thereby increasing

LSP's idle capacity and reducing environmental efficiency. For the OFP, the reselling model is preferable when freight services yield sufficient returns. Otherwise, the manufacturer may favor agency cooperation to avoid the risks of direct channel conflict. Strategic alignment between them is therefore conditional. Notably, in scenarios characterized by low freight profitability and weak market expansion, a prisoner's dilemma may emerge. In such cases, deeper collaboration and well-designed value-sharing mechanisms are essential to ensure incentive compatibility and sustainable cooperation.

Finally, we examine equilibrium outcomes under alternative power structures. We find that the relative scale of the platform's freight supply is a critical determinant. When LSPs rely heavily on the OFP for freight demand, a manufacturer-led structure induces the platform to invest more in matching capabilities, thereby expanding demand and improving manufacturer profitability. In contrast, when the OFP controls abundant freight resources, a platform-led structure enhances market coverage but does not necessarily improve manufacturer profits. In such cases, the manufacturer is incentivized to retain pricing authority to safeguard margins.

Our contributions are fourfold: (1) We examine the effects of cooperative sales and identify equilibrium strategies under different power structures; (2) we reveal cross-channel spillovers by modeling the OFP's dual role in freight and vehicle markets; (3) we demonstrate that reselling cooperation can yield win–win outcomes, particularly when supported by matched dominance structures; (4) we find that LSP heterogeneity and platform capabilities jointly influence strategic preferences, and strong platform reselling acceptance and market reach may, paradoxically, weaken cooperation effectiveness.

The remainder of the paper is structured as follows: Section 2 reviews the related literature. Section 3 introduces the cooperation models, followed by equilibrium analysis in Section 4. Section 5 explores cooperation strategy selection, and Section 6 examines the impact of channel power structures. Section 7 concludes with key findings and directions for future research.

2. Literature review

2.1. Promotion of new energy commercial vehicles

The growing environmental impact of freight transport has intensified efforts to promote NECVs as a key decarbonization pathway [24]. From the users' perspective, studies focus on the adoption behavior of LSPs, identifying technological, economic, and environmental factors as key determinants. For instance, Zhang et al. [25], based on an empirical study of 288 trucking fleets in Jiangsu Province, revealed that vehicle performance, operating costs, and policy subsidies significantly influence LSPs' willingness to adopt alternative fuel vehicles. Henrik and Emil [26] further demonstrated the supporting role of scale economies in technological transition. Cantillo et al. [27] highlighted that the high total cost of ownership remains a major adoption barrier. Recent conclusions on NECVs' cost competitiveness remain mixed. Scorrano et al. [28] argued that light-duty electric vehicles are cost-competitive in urban areas, and Schiffer et al. [29] showed that the electrification of medium-range logistics fleets can be both economically viable and environmentally beneficial under specific conditions. Conversely, Winkelmann et al. [30] advocated delaying adoption to avoid sunk costs, suggesting a trade-off between technology upgrading and cost efficiency.

Existing studies involving manufacturers' strategic decisions largely center on the passenger vehicle market, focusing on product-line design and new energy vehicle (NEV) promotion under various environmental policies [31–33]. From the perspective of production and sales collaboration, Liao et al. [3] analyzed optimal cooperation strategies between the traditional fuel vehicle and NEV manufacturer under a dual-credit policy, challenging the traditional notion of a zero-sum game. Fan et al. [34], taking a vertical cooperation perspective, investigated how partnerships between manufacturers and upstream battery suppliers affect NEV demand and profitability. This study also adopts the lens of vertical sales cooperation, but differs by taking the freight sector into consideration. Rather than exploring alliances between manufacturers or between manufacturers and battery suppliers, we observe industry practices and the potential impact of freight service revenues on the sales of NECVs, analyzing the strategic cooperation between the NECV manufacturer and downstream platform, offering new insights into how freight market dynamics shape NECV sales.

2.2. Values of online freight platforms in vehicle promotion

Online freight platforms enhance logistics efficiency by aggregating fragmented demand and improving supply-demand matching [35]. Acting as intermediaries in two-sided markets, platforms generate strong network effects that can influence NECV adoption [8,36]. While research on car-sharing and ride-hailing has explored how platforms promote green mobility [37,38], studies focusing on the freight sector remain scarce. Yan et al. [11] suggested that platforms can promote hydrogen trucks via preferential terms, but the collaborative dynamics between manufacturers and online freight platforms have received less attention.

Although direct research on sales cooperation in freight contexts remains limited, relevant insights can be drawn from the classical literature on online retailing. As intermediaries in two-sided markets, online freight platforms derive marketing value from aggregating demand, paralleling the enabling roles of distribution and social media platforms [39,40]. Prior studies have shown that third-party platforms not only complement traditional retail channels but also reshape channel power dynamics [12,41]. Mantin et al. [41] noted that retailers can leverage platforms to strengthen their bargaining positions against manufacturers, and Xia et al. [42] claimed that suppliers can charge higher prices after collaborating with downstream distribution platforms. Similarly, online freight platforms entering the vehicle sales market gain access to new revenue streams while capitalizing on their strengths in demand coordination and service delivery, potentially generating synergies in sales promotion.

Unlike conventional platform-channel settings in which product demand is primarily determined at the point of sale, NECV demand in freight markets is endogenously shaped by post-sale operational performance. Specifically, freight service capability affects vehicle utilization and operating profitability, which in turn influence LSPs' vehicle adoption incentives. This usage-driven demand mechanism fundamentally links service operations with product sales decisions and distinguishes the present study from existing platform-channel and vehicle adoption research. In the passenger vehicle sector, Guo et al. [22], drawing on the case of BMW's proprietary sharing platform, demonstrated the significant influence of product-sharing value on automakers' platform strategy decisions. Similarly, Zhang et al. [20] and Huang et al. [19] explored manufacturers' optimal strategic choices from the perspective of sharing participation. Although Sun et al. [23] incorporated logistics demand characteristics into their analytical framework from the perspective of NECV promotion via online freight platforms, they did not sufficiently capture the platform's role as a two-sided market intermediary in demand aggregation, information matching, and market outreach.

In summary, the complementary relationship between NECV sales and freight services, as well as the emerging post-cooperation competition, redefines traditional partnership models and performance outcomes. Building on this literature, our study explores how cross-functional coordination between sales and service activities creates shared value, thereby extending freight platform research and informing NECV deployment strategies.

2.3. Platform sales cooperation modes

The sales formats in platform-based channels can be broadly classified into two modes, according to the transaction structure: the agency model and the reselling model [43]. In the agency model, manufacturers retain pricing control while platforms provide marketing exposure and customer access [44]. In the reselling model, platforms set prices and may offer bundled services to stimulate demand [17]. The coexistence of traditional and platform channels also creates a dual-channel structure, which can lead to channel competition, demand substitution, and market cannibalization [45,46]. Still, Tsay and Agrawal [47] showed that adding a direct channel can create mutual benefits by leveraging the manufacturer's ability to stimulate demand. Recent studies extend this perspective. Zheng and Yu [48] suggested that the manufacturer can adopt an equal pricing strategy when introducing a direct channel, thereby alleviating channel conflict. Song et al. [39] showed that collaboration between social media and retail platforms can reduce the negative effects of demand diversion and generate triple-win outcomes. However, Martín-Herrán & Sigué [49] cautioned that multichannel retailing is not universally beneficial, especially when complex vertical interactions exist between manufacturers and retailers. This is particularly relevant in the context of NECV promotion through online freight platforms. The relationship here is not merely vertical but also interdependent: the platform's freight service quality directly affects the utility of the vehicle asset. Therefore, the cooperative benefits between NECV manufacturers and OFPs, shaped by this unique interdependence, warrant further exploration.

Building on the distinctive features of various cooperation modes, a growing body of research has examined equilibrium sales strategy selection. Abhishek et al. [21] highlighted that reselling becomes less attractive when platform-driven spillovers are weak. Mao et al. [12] showed that direct cooperation can hurt retailers but improve total performance. Chen et al. [15] further underscored the role of service efficiency and power structure, noting that the agency model is typically optimal when the manufacturer holds greater power. Emerging research also challenges traditional wisdom with the changing operational environment. Wei et al. [50] challenged the conclusion that platforms only favor agency models under high commissions when cause marketing exists. Huang et al. [51] suggested that the equilibrium channel strategy depends on channel selection power, the degree of complementarity, commission rates, and brand spillover effects. The above studies underscore that equilibrium strategies are shaped by platform capabilities and market dynamics. However, they focus narrowly on the sales stage, overlooking how post-sale operations can influence channel outcomes. In the context of NECV promotion, online freight platforms not only act as marketing intermediaries but also as operational coordinators whose freight capacity affects vehicle utilization and adoption. Although Tao et al. [52] explored sales models in the context of NEV sales, they did not account for the freight-specific usage phase. Our study fills this gap by integrating the sale and service role of the platform, comparing agency and reselling cooperation models, and examining how channel power structure shapes equilibrium outcomes in a freight-dependent setting.

This study contributes to the existing literature in several aspects. First, we enrich NECV adoption research by introducing a supply chain collaboration perspective that integrates NECV sales with freight service operations. Second, we deepen the understanding of OFPs' broader value proposition by analyzing the dual role in marketing and operations. Third, we extend channel configuration and research on sales mode selection strategies by integrating freight-side complementarity and comparing sales cooperation models under varying market structures.

3. The model

We consider a three-tier supply chain consisting of a new energy commercial vehicle (NECV) manufacturer, an online freight platform (OFP), and a continuum of logistics service providers (LSPs). LSPs decide whether to purchase NECVs based on their expected profitability from freight operations. The potential market size for vehicle sales prior to cooperation is denoted by a, where $0 < a < 1$. For analytical tractability, we normalize both the maximum service capacity of each LSP and the unit revenue of a single completed freight order for LSPs to 1 [8]. This normalization simplifies analytical derivation without altering the core qualitative conclusions of the model. LSPs obtain freight demand from two independent sources. The first is a private market, which represents long-term contractual relationships with shippers. Demand from the private market is characterized by a capacity fulfillment rate v, which captures the share of an LSP's total capacity that is utilized by private contracts. We assume that v follows a uniform distribution over the interval $[0,1]$ [53–55], and accordingly, an LSP has idle capacity of $1 - v$ that can be used to fulfill spot orders [8]. We assume that only a fraction $\beta \in (0,1)$ of LSPs choose to utilize idle capacity by accepting orders from the OFP, while the remaining $1 - \beta$ LSPs rely exclusively on private-market demand due to factors such as limited familiarity with the platform, trust concerns, or adoption costs.

From the OFP's perspective, freight-side revenue increases with LSP participation and consists entirely of service commissions charged to LSPs and intermediary fees collected from shippers, consistent with the operational model of mainstream OFPs such as Lalamove and Full Truck Alliance. Let $f > 0$ denote the average unit commission and intermediary fee revenue that the OFP earns from each completed freight order fulfilled by a participating LSP. This parameter is the core representation of the OFP's freight-side income stream in our model. The platform holds a total aggregated spot freight supply pool of size $n' \in (0,1)$, which represents the upper limit of shippers' orders that the OFP can access in the market. To match these freight orders with LSPs' idle capacity, the OFP makes a strategic investment $\lambda > 0$ in vehicle-freight matching capability (e.g., AI-driven matching algorithm optimization, big data system upgrading). The effective matching efficiency delivered by this investment is denoted as $\mu\lambda$, where $\mu \in (0,1)$ is an exogenous parameter capturing the OFP's investment efficiency: a higher μ means the OFP can translate the same amount of investment into stronger matching performance, which aligns with the operational practice of leading OFPs [56].

Given that both μ (investment efficiency) and n' (total freight supply pool) are exogenous, determined by the OFP's long-term operational capability and market environment, we define the platform's effective freight supply as $n = \mu n'$. This core parameter represents the maximum volume of freight orders that the OFP can reliably and successfully match to participating LSPs, which directly sets the upper bound of LSPs' idle capacity utilization via the platform. Let Q denote the potential mass of LSPs that obtain non-negative expected utility from platform participation. Since only a fraction β of LSPs join the platform, and only a proportion of the vehicle market is initially active, the total number of participating LSPs with available idle capacity on the platform is $\beta a Q$. Thus, the expected matching probability for idle capacity is given by $\lambda \frac{n}{\beta a Q}$. This reveals a core trade-off: both higher effective freight supply n and greater matching investment λ increase the matching probability and LSPs' expected utility, while a larger number of participating LSPs (higher $\beta a Q$) dilutes the matching probability for each individual LSP. This gives rise to a negative same-side network effect that may discourage additional LSP participation. Table 1 summarizes an overview of the key symbols.

Table 1. Notations.

Symbols	Descriptions
Parameters	
a	Potential NECV demand before cooperation, $0 < a < 1$.
n	Platform's available freight supply scale, $0 < n < 1$.
β	Proportion of LSPs that choose to obtain orders from the OFP, $0 < \beta < 1$.
f	Average unit freight revenue brought by LSP.
θ	Revenue-sharing rate of incremental demand in agency cooperation mode, $0 < \theta < 1$.
τ	LSPs' acceptance of platform's reselling model, $0 < \tau < 1$.
d_t, d_o	Vehicle demand in the traditional channel and the platform channel, respectively. $d = d_t + d_o$ denotes the total demand of dual channels.
π_M, π_{OFP}	Profits of the manufacturer and the OFP, respectively.
Decision variables	
λ	Investment cost in vehicle-freight matching capabilities, $\lambda > 0$.
w_o, m_o	Wholesale price and retail markup in the reselling channel.
p_t, p_o	Vehicle retail prices in the traditional channel and the platform channel, respectively.

Motivated by practices observed on platforms such as Lalamove and Shengsheng Freight, we consider two cooperation strategies between the NECV manufacturer and the OFP. Under the agency cooperation strategy (Model A), the OFP provides promotional exposure and access to LSPs, while the manufacturer retains pricing authority and shares a fraction of the incremental vehicle sales revenue with the platform. Under the reselling cooperation strategy (Model R), the OFP purchases vehicles from the manufacturer at a wholesale price and resells them to LSPs through its own distribution channel. Table 2 provides an overview of all cooperation modes and key decision variables.

Table 2. Decision variables in different models.

Models		Decision variables
Without cooperation (Model T)		λ^{T*}, p_t^{T*}
Agency cooperation (Model A)		λ^{A*}, p_t^{A*}
Reselling cooperation (Model R)	Manufacturer dominated (Model M)	λ^M, m_o^M, w_o^M, p_t^M
	Online freight platform dominated (Model M)	λ^P, m_o^P, w_o^P, p_t^P

Relative to the no-cooperation benchmark (Model T), both cooperation strategies expand the vehicle market by leveraging the platform's large LSP base and targeted promotion capability. We capture this effect by assuming that the potential market size expands from a to 1 following cooperation, where $1 - a$ represents the platform's market expansion capability [57]. The manufacturer and the OFP are assumed to be economically rational and strategically interact to maximize their respective profits. The timing of decisions under each cooperation mode is illustrated in Figure 1. All scenarios share a common initial stage: the OFP first determines its investment level in vehicle-freight matching capability. This upfront investment timing is justified by the fact that matching capability construction (e.g., AI-driven matching algorithm optimization, big data system upgrading) represents long-term, irreversible operational infrastructure investment for the platform. After the OFP's upfront investment, the game then proceeds along three core branches, as follows: (1) No cooperation: the manufacturer independently sets the vehicle retail price. (2) Agency cooperation: the manufacturer (as channel leader) first sets wholesale and retail prices, then the OFP determines its retail markup. (3) Reselling cooperation: under a manufacturer-led structure, the manufacturer sets the wholesale price first, followed by the OFP's retail markup; under a platform-led structure, the OFP announces its markup first, with the manufacturer then setting the wholesale price. After all pricing decisions are finalized, LSPs make NECV purchase and platform participation decisions.

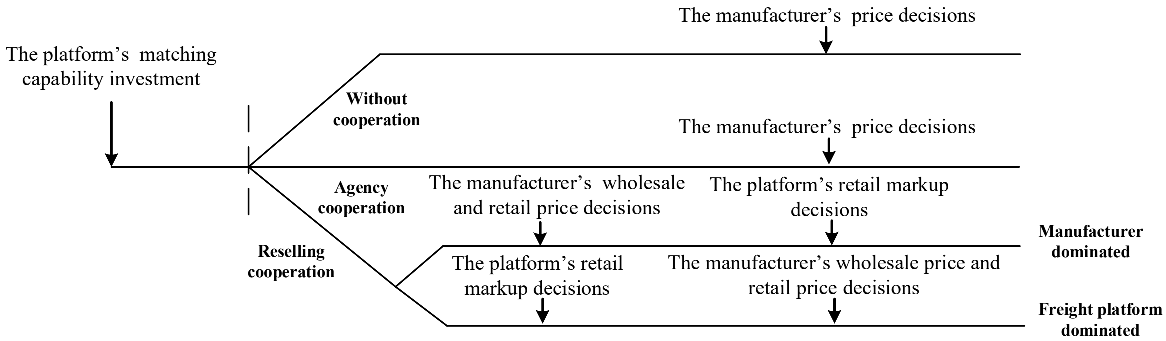


Figure 1. The sequence of events.

3.1. Without online freight platform

In the absence of the online freight platform, all logistics service providers rely exclusively on the private market to obtain service demand (Model N). The utility of LSPs is given by $u_0^N = v - p_t^N$. When $v_1 = p_t^N$, LSPs are indifferent between purchasing and not purchasing a vehicle. Consequently, vehicle demand in the private market is given by $d_t^N = a(1 - p_t^N)$, where $a \in (0,1)$ represents the size of the potential market. The NECV manufacturer determines the vehicle price to maximize its profit. The profit function is $\pi_M^N = ap_t^N(1 - p_t^N)$. Applying backward induction, the equilibrium outcomes are obtained as $p_t^{N*} = \frac{1}{2}$, $d_t^{N*} = \frac{a}{2}$, $\pi_M^{N*} = \frac{a}{4}$. This benchmark case serves as a reference point for subsequent analyses, allowing us to isolate and evaluate the sales spillover effects generated by the OFP.

3.2. Without cooperation (Model T)

For LSPs that obtain service demand only from the private market, the utility function can be defined as $u_0^T = v - p_t^T$. For LSPs that obtain service demand from both the private market and the OFP, the utility function can be defined as $u_1^T = v + \lambda^T \frac{n}{\beta a Q}(1 - v) - p_t^T$, where $\lambda^T \frac{n}{\beta a Q}(1 - v)$ also captures the spillover effect of the OFP on vehicle sales promotion.

Accordingly, the LSP relying exclusively on the private market is indifferent between purchasing and not purchasing a NECV when the capacity fulfillment rate satisfies $v_1 = p_t$, and for LSPs who obtain service from platform, the indifferent point is given by $v_2 = \frac{n\lambda^T - aQ\beta p_t^T}{n\lambda^T - aQ\beta}$. Given that the cumulative distribution of LSPs with valuation above v_2 satisfies $Q = \int_{v_2}^{1} f(v)dv = 1 - v_2$, we derive $Q = 1 + \frac{\lambda^T n}{a\beta} - p_t^T$. The demand in the traditional channel is $d_t^T = a(1-\beta)(1-p_t^T) + a\beta(1 + \frac{\lambda^T n}{a\beta} - p_t^T)$, and the potential volume of LSPs who obtain freight orders via the OFP is $a\beta Q = a\beta(1 + \frac{\lambda^T n}{a\beta} - p_t^T)$, as shown in Figure 2.

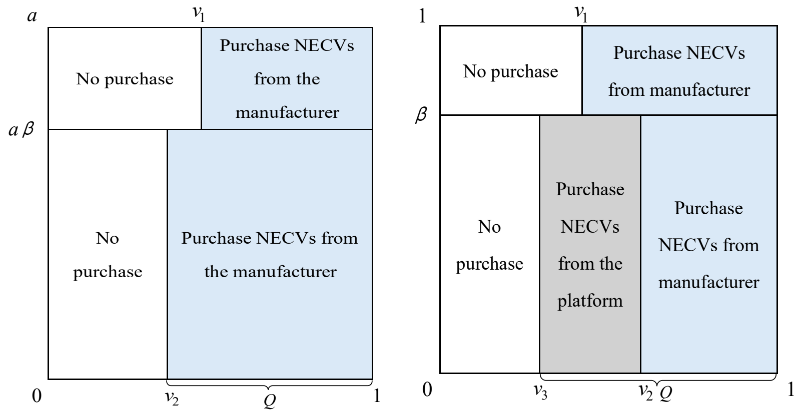


Figure 2. LSPs' decision distributions.

The manufacturer's revenue is derived solely from vehicle sales, while the OFP earns income through freight service operations. However, the OFP also bears the matching cost incurred during the transaction process, which increases with the scale of LSP participation. Specifically, as more LSPs join the platform, the complexity and operational burden of matching rise, leading to escalating coordination costs. The profit functions for the manufacturer and the OFP are given by:

$$\begin{cases} \max_{p_t^T} \pi_M^T = p_t^T\left(a(1-\beta)(1-p_t^T) + a\beta\left(1 + \frac{\lambda^T n}{a\beta} - p_t^T\right)\right) \\ \max_{\lambda^T} \pi_{OFP}^T = (f - \lambda^T)a\beta\left(1 + \frac{\lambda^T n}{a\beta} - p_t^T\right) \\ s.t. 0 < 1 - v_1, 1 - v_2 < 1 \end{cases} \tag{1}$$

Following the sequential decision structure illustrated in Figure 1, we apply backward induction to characterize the subgame perfect equilibrium. The resulting equilibrium strategies of the manufacturer and the OFP are formally stated in Table 3, and derivations of equilibrium solutions and constraints are provided in the Appendix.

Corollary 1. Under Model T, the impacts of key parameters on the equilibrium outcomes are specified as follows: (1) Impact of the unit freight revenue f of the OFP: $\frac{\partial \lambda^{T*}}{\partial f} > 0$, $\frac{\partial p_t^{T*}}{\partial f} > 0$, $\frac{\partial d^{T*}}{\partial f} > 0$, $\frac{\partial \pi_M^{T*}}{\partial f} > 0$, $\frac{\partial \pi_{OFP}^{T*}}{\partial f} > 0$; (2) impact of the freight supply n: $\frac{\partial \lambda^{T*}}{\partial n} > 0$, $\frac{\partial p_t^{T*}}{\partial n} > 0$, $\frac{\partial d^{T*}}{\partial n} > 0$, $\frac{\partial \pi_M^{T*}}{\partial n} > 0$, $\frac{\partial \pi_{OFP}^{T*}}{\partial n} > 0$; (3) impact of the participation rate of OFP β: $\frac{\partial \lambda^{T*}}{\partial \beta} < 0$, $\frac{\partial p_t^{T*}}{\partial \beta} < 0$, $\frac{\partial d^{T*}}{\partial \beta} < 0$, $\frac{\partial \pi_M^{T*}}{\partial \beta} < 0$, $\frac{\partial \pi_{OFP}^{T*}}{\partial \beta} > 0$.

Corollary 1 highlights a shared-interest relationship between the manufacturer and the OFP: enhanced platform capabilities, higher freight returns, and better demand integration boost the manufacturer's profitability. However, as LSP participation grows, the platform reduces its investment in matching efficiency due to rising marginal costs. Also, the platform benefits from reduced matching costs and an expanded provider base, improving its own profitability. This result is consistent with Lyu et al. [58]: as market thickness increases, intensified competition outweighs the value enhancement, such that the marginal contribution of additional same-side users turns negative.

3.3. Agency cooperation (Model A)

Under Model A, the OFP provides a sales channel and displays targeted advertisements on its website or app. In return, the manufacturer shares a portion of the incremental sales revenue generated from enhanced exposure and expanded market reach [39]. We assume that the additional profit generated from expanded vehicle demand is shared between the manufacturer and the OFP at a proportion $\theta \in (0,1)$. Based on the exposure effect, we assume that the potential market size increases from $a \in (0,1)$ to 1. The supply chain structure is shown in Figure 3.

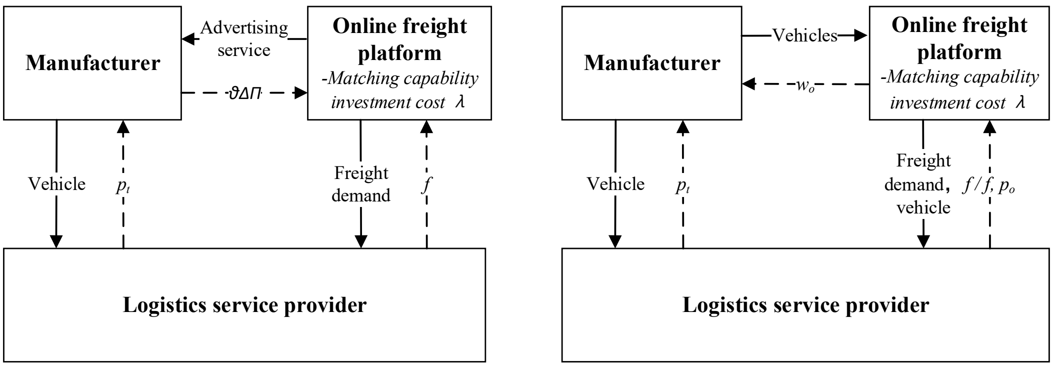


Figure 3. Agency model vs. reselling model.

Consistent with the formulation in Section 3.2, the vehicle demand from the traditional channel is expressed as $d_t^A = (1-\beta)(1-p_t^A) + \beta(1+n\lambda^A - p_t^A)$, and the volume of LSPs acquiring freight service through the platform is $\beta Q = \beta(1+n\lambda^A - p_t^A)$. The incremental demand attributable to market expansion is denoted by Δd_t, where $\Delta d_t = (1-a)(1-p_t^A)$.

In this setting, the manufacturer earns revenue from vehicle sales, while the OFP benefits both from freight service income and shared sales returns. Then, the profit functions of the manufacturer and the OFP are given by:

$$\begin{cases} \max\limits_{p_t^A} \pi_M^A = p_t^A\big((1-\beta)(1-p_t^A) + \beta(1+n\lambda^A - p_t^A)\big) - \theta p_t^A(1-a)(1-p_t^A) \\ \max\limits_{\lambda^A} \pi_{OFP}^A = f\beta(1+n\lambda^A - p_t^A) + \theta p_t^A(1-a)(1-p_t^A) - \lambda\beta(1+n\lambda^A - p_t^A) \\ \qquad s.t. 0 < 1-v_1, 1-v_2 < 1 \end{cases} \quad (2)$$

Using backward induction, we obtain equilibrium results in Table 3.

Corollary 2. Under Model A, the impacts of the platform's capability and LSPs' characteristics on equilibrium decisions are as follows:

(1) i) $\frac{\partial \lambda^{A*}}{\partial f} > 0$, $\frac{\partial p_t^{A*}}{\partial f} > 0$, $\frac{\partial \pi_M^{A*}}{\partial f} > 0$, $\frac{\partial \pi_{OFP}^{A*}}{\partial f} > 0$; $\frac{\partial p_t^{A*}}{\partial n} > 0$, $\frac{\partial \pi_M^{A*}}{\partial n} > 0$, $\frac{\partial \pi_{OFP}^{A*}}{\partial n} > 0$; $\frac{\partial \lambda^{A*}}{\partial \beta} < 0$, $\frac{\partial p_t^{A*}}{\partial \beta} < 0$, $\frac{\partial \pi_M^{A*}}{\partial \beta} < 0$, $\frac{\partial \pi_{OFP}^{A*}}{\partial \beta} > 0$.

ii) The demand is determined by the initial market scale a and the revenue sharing ratio θ: If $a > \frac{-1+2\theta}{2\theta}$, $\frac{\partial d^{A*}}{\partial f} > 0$, $\frac{\partial d^{A*}}{\partial n} > 0$, $\frac{\partial d^{A*}}{\partial \beta} < 0$; otherwise, $\frac{\partial d^{A*}}{\partial f} < 0$, $\frac{\partial d^{A*}}{\partial n} < 0$, $\frac{\partial d^{A*}}{\partial \beta} > 0$.

(2) The impact of freight supply n on the platform's investment in matching capability is non-monotonic: when $a < \min\{\frac{\sqrt{8n+(n-\beta)^2}-4-n+\beta+4\theta}{4\theta}, \frac{n\theta+\beta\theta-\beta}{n\theta+\beta\theta}\}$ and $f > \frac{2\beta(1-(1-a)\theta)(\beta+(1-a)(4-n-\beta)\theta-2(1-a)^2\theta^2-2)}{(-1+a)n^2\theta(2-\beta+2(-1+a)\theta)}$ shows a trend of first increasing and then decreasing with the increase of n; otherwise, $\frac{\partial \lambda^{A*}}{\partial n} > 0$.

Corollary 2 shows that under strong platform expansion capability and high revenue-sharing ($\theta > \frac{1}{2}$ and $a < \frac{-1+2\theta}{2\theta}$), increases in freight benefits or supply scale may distort incentives, where the manufacturer raises prices to offset the revenue-sharing loss, thus reducing overall vehicle purchase. Over-incentivizing the platform may thus suppress sales and harm consumer surplus. Moreover, the platform's investment in matching is non-monotonic, which initially rises with freight supply but declines once marginal returns cannot make up for the escalating matching costs, prompting the platform to reduce investment.

3.4. Reselling cooperation (Model R)

In Model R, the OFP purchases vehicles from the manufacturer at a wholesale price w_o and resells them to potential LSPs with a retail markup m_o, thereby providing an alternative purchasing channel. We assume LSPs that exclusively operate in private markets do not choose to purchase vehicles through the OFP. Then, LSPs can be classified into three groups, as shown in Figure 2: (1) LSPs that do not engage with the OFP for either vehicle procurement or freight services; (2) LSPs that utilize OFP services but purchase vehicles directly from the manufacturer; and (3) LSPs that acquire services and purchase vehicles through the OFP.

For LSPs relying solely on the private market for service demand, the utility function is defined as $u_0^R = v - p_t^R$. For those using platform services but purchasing vehicles directly from the manufacturer, the utility is $u_{1t}^R = v + \lambda^R \frac{n}{\beta Q}(1-v) - p_t^R$, and for LSPs acquiring both services and vehicles through the OFP, the utility is $u_{1o}^R = \tau v + \lambda^R \frac{n}{\beta Q}(1-v) - (m_o^R + w_o^R)$, where τ represents acceptance of platform reselling, and $1-\tau$ reflects the perceived valuation discount when purchasing via the platform [16]. The utility discount $(1-\tau)v$ decreases as LSPs become more dependent on the platform. Specifically, as a greater share of freight demand is met through the platform, LSPs exhibit increased acceptance of platform-mediated vehicle purchases due to positive spillovers: sustained service engagement fosters trust, thereby enhancing willingness to buy from the platform.

For LSPs who obtain freight demand solely from the private market, the indifference point between purchasing and not purchasing a vehicle is given by $v_1 = p_t^R$. For LSPs who acquire freight demand through the platform, the indifference point between the two purchase options, derived from $u_{1t}^R = u_{1o}^R$, is $v_2 = \frac{p_t^R - m_o^R - w_o^R}{1-\tau}$. Additionally, based on the condition $u_{1o}^R = 0$, i.e., the LSP is indifferent between purchasing and not purchasing through the platform, the corresponding threshold becomes $v_3 = \frac{n\lambda^R - Q\beta(m_o^R + w_o^R)}{n\lambda^R - Q\beta\tau}$, and we can obtain $Q = \frac{n\lambda^R + \beta\tau - \beta(m_o^R + w_o^R)}{\beta\tau}$, based on the relationship $Q = 1 - v_3$. The demand in the two channels can thus be expressed as $d_t^R = (1-\beta)\int_{v_1}^{1} f(v)dv + \beta\int_{v_2}^{1} f(v)dv = \frac{1-\tau+\beta(m_o^R+w_o^R)-(1-(1-\beta)\tau)p_t^R}{1-\tau}$, and $d_o^R = \beta\int_{v_3}^{v_2} f(v)dv = \frac{n\lambda^R(1-\tau)+\beta(\tau p_t^R - m_o^R - w_o^R)}{(1-\tau)\tau}$, respectively; the potential amount of LSPs who obtain freight services via the OFP is $\beta Q = \frac{n\lambda^R + \beta\tau - \beta(m_o^R + w_o^R)}{\tau}$. Thus, the profit functions of manufacturer and OFP are as follows:

$$\begin{cases} \max\limits_{p_t^R, w_o^R} \pi_M^R = p_t^R\left(\dfrac{1-\tau+\beta(m_o^R+w_o^R)-(1-(1-\beta)\tau)p_t^R}{1-\tau}\right) + w_o^R\dfrac{n\lambda^R(1-\tau)+\beta(\tau p_t^R - m_o^R - w_o^R)}{(1-\tau)\tau} \\ \max\limits_{\lambda^R, m_o^R} \pi_{OFP}^R = (f-\lambda^R)\dfrac{n\lambda^R+\beta\tau-\beta(m_o^R+w_o^R)}{\tau} + m_o^R\dfrac{n\lambda^R(1-\tau)+\beta(\tau p_t^R - m_o^R - w_o^R)}{(1-\tau)\tau} \\ s.t.\, 0 < 1-v_1, 1-v_3 < 1 \end{cases} \tag{3}$$

Considering different market power structures under Model R, we examine two distinct supply chain configurations: the manufacturer-led structures (Model M) and platform-led structures (Model P). The corresponding game sequences are depicted in Figure 1, and the equilibrium results are shown in Table 3.

Table 3. Equilibrium decisions and optimal profits in Model i, $\{i = T, A, P, M\}$.

	Model T	Model A	Model P	Model M
λ^{i*}	$\frac{f}{2} - \frac{a\beta}{2n(2-\beta)}$	$\frac{(1-(1-a)\theta)(fn(-2+\beta)+\beta+(1-a)(2fn-\beta)\theta)}{n(2\beta(1-(1-a)\theta-4)-(1-a)\theta(n+4\theta-4a\theta-8))}$	$\frac{\beta(2\beta\tau+f(\beta-\beta\tau+n(-1-3\tau+2\beta\tau)))}{(n-\beta)^2-(n^2+2n(3-2\beta)\beta+\beta^2)\tau}$	$\frac{\beta(4\beta\tau+f(\beta-\beta\tau+n(-1-7\tau+4\beta\tau)))}{(n-\beta)^2-(n^2+2n(7-4\beta)\beta+\beta^2)\tau}$
p_t^{i*}	$\frac{1}{2} + \frac{fn}{2a} - \frac{\beta}{4-2\beta}$	$\frac{1}{2} + \frac{fn(-2+\beta)+\beta+(-1+a)(-2fn+\beta)\theta}{4\beta(1-(1-a)\theta)-2(1-a)\theta(n+4\theta-4a\theta-8)-8}$	$\frac{1}{2} + \frac{n\beta(2\beta\tau+f(\beta-\beta\tau+n(-1-3\tau+2\beta\tau)))}{2(n-\beta)^2-2(n^2+2n(3-2\beta)\beta+\beta^2)\tau}$	$\frac{1}{2} + \frac{n\beta(4\beta\tau+f(\beta-\beta\tau-n(1+7\tau-4\beta\tau)))}{2(n-\beta)^2-2(n^2+2n(7-4\beta)\beta+\beta^2)\tau}$
p_o^{i*}	--	--	$\frac{n\tau(\beta+2f(1-\beta)\beta(1-\tau)+(7-6\beta)\beta\tau-n(1-2f-\tau+2f(1-\beta)^2\tau))}{2(n^2+2n(3-2\beta)\beta+\beta^2)\tau-2(n-\beta)^2}$	$\frac{\tau(n\beta(2+f(8-5\beta)(1-\tau)+18\tau-12\beta\tau)-n^2\left(1-\tau-f\left(8-8\tau-\beta(3-11\tau+4\beta\tau)\right)\right)+3\beta^2(1-\tau))}{2(n^2+2n(7-4\beta)\beta+\beta^2)\tau-2(n-\beta)^2}$
w_o^{i*}	--	--	$\frac{(1-\tau)(\beta(n+\beta)\tau-fn(n-\beta)(1+(1-\beta)\tau))}{n^2(1-\tau)+\beta^2(1-\tau)-2n\beta(1+(3-2\beta)\tau)}$	$\frac{(1-\tau)(\beta(n+3\beta)\tau-fn(n-\beta+n(1-\beta)\tau-(5-3\beta)\beta\tau))}{n^2(1-\tau)+\beta^2(1-\tau)-2n\beta(1+(7-4\beta)\tau)}$
d_t^{i*}	$\frac{fn}{4} + \frac{3a}{4} - \frac{a}{4-2\beta}$	$\frac{3\beta-4+(1-a)(8-n-5\beta)\theta-2(1-a)^2(2-\beta)\theta^2+fn(1-2(1-a)\theta)(\beta+2\theta-2a\theta-2)}{-8+4\beta(1-(1-a)\theta)+2(1-a)\theta(8-n-4\theta+4a\theta)}$	$\frac{\beta^2(1-\tau+\beta\tau)+n^2\left(1-\tau+f\beta(1+\tau-\beta\tau)\right)-n\beta(2+6\tau-5\beta\tau-f\beta(1+\tau-\beta\tau))}{2(n-\beta)^2-2(n^2+2n(3-2\beta)\beta+\beta^2)\tau}$	$\frac{\beta^2(1-\tau+2\beta\tau)+n^2\left(1-\tau-f\beta(1+3\tau-2\beta\tau)\right)-n\beta(2+2(7-5\beta)\tau-f\beta(1+3\tau-2\beta\tau))}{2(n-\beta)^2-2(n^2+2n(7-4\beta)\beta+\beta^2)\tau}$
d_o^{i*}	--	--	$\frac{\beta(fn(2-\beta)(n+\beta)-\beta(n-\beta))}{2(n^2+2n(3-2\beta)\beta+\beta^2)\tau-2(n-\beta)^2}$	$\frac{\beta((n-\beta)\beta+fn(-2+\beta)(n+\beta))}{(n-\beta)^2-(n^2+2n(7-4\beta)\beta+\beta^2)\tau}$
π_M^{i*}	$\frac{(fn(2-\beta)+a(4-3\beta))^2}{16a(2-\beta)^2}$	$\frac{(1-(1-a)\theta)\begin{pmatrix}4+2fn-3\beta-fn\beta-(1-a)\\(8-(1-2f)n-3\beta)\theta+4(1-a)^2\theta^2\end{pmatrix}^2}{4(-4+2\beta+(1-a)(8-n-2\beta)\theta-4(1-a)^2\theta^2)^2}$	$\frac{A}{4(n^2(1-\tau)+\beta^2(1-\tau)-2n\beta(1+(3-2\beta)\tau))^2}$	$\frac{B}{4(n^2(1-\tau)+\beta^2(1-\tau)-2n\beta(1+(7-4\beta)\tau))^2}$
π_{OFP}^{i*}	$\frac{4afn}{fn(2-\beta)+a\beta} - \frac{2a}{2-\beta}$	$\frac{f^2n^2(2-\beta-2(1-a)\theta)^2-2(1-a)n\beta\theta(1-(1-a)\theta)+2fn\beta(2-\beta-(1-a)(4-n-\beta)\theta+2(1-a)^2\theta^2)+(\beta-(1-a)\beta\theta)^2+(1-a)n\theta(4-(1-a)\theta(8-n-4(1-a)\theta))}{4n(4-2\beta(1-(1-a)\theta)-(1-a)\theta(8-n-4\theta+4a\theta))}$	$\frac{\beta^3\tau+f^2n^2(2-\beta)\beta(1+\tau-\beta\tau)+fn\beta(\beta-n(1-\tau)+(3-2\beta)\beta\tau)}{2(n^2+2n(3-2\beta)\beta+\beta^2)\tau-2(n-\beta)^2}$	$\frac{n(2-\beta)\beta(f(1-\tau)+4\tau)+\beta^2(1-\tau)+n^2(1-\tau+f(2-\beta)(3+5\tau-4\beta\tau))}{2(n^2+2n(7-4\beta)\beta+\beta^2)\tau-2(n-\beta)^2}$

Corollary 3. The OFP's equilibrium retail markup satisfies $m_o^{i*} > 0$ if $\beta < \beta_1$ and $f > f_1$; otherwise, $m_o^{i*} < 0$, $i \in \{P, M\}$.

Corollary 3 reveals that the OFP may strategically subsidize vehicle purchases to stimulate adoption by LSPs. This pricing strategy is particularly pronounced when the unit freight service revenue f is high, yet the proportion of LSPs participating in the platform-mediated freight market β remains relatively low. Under such conditions, subsidizing vehicles serves as an investment to enlarge the OFP's vehicle base, which subsequently increases freight service volume and enhances overall OFP profitability. This finding is illustrated in practice by OFPs such as Lalamove, which frequently bundle vehicle purchase discounts with value-added services, including priority order matching and customized financing options, to strengthen the value proposition for LSPs. The result also aligns with Chen et al. [15], who observe that direct sales does not invariably reduce final prices. By internalizing the cross-side interaction between vehicle sales and freight service utilization, the OFP dynamically adjusts its pricing to balance adoption incentives with revenue objectives. Consequently, the classical double-marginalization problem typical of conventional reselling channels is alleviated.

Corollary 4. Under Model R, the impacts of the reselling channel acceptance τ on equilibrium results are as follows:

(1) If $n < \beta$, $\frac{\partial \lambda^{i*}}{\partial \tau} > 0$, $\frac{\partial d_t^{i*}}{\partial \tau} > 0$; otherwise, $\frac{\partial \lambda^{i*}}{\partial \tau} < 0$, $\frac{\partial d_t^{i*}}{\partial \tau} < 0$; (2) $\frac{\partial d_o^{i*}}{\partial \tau} < 0$.

Corollary 4 reveals that an increase in reselling channel acceptance τ does not necessarily lead to proportional growth in platform investment or overall demand and may yield contrasting effects. When the OFP's freight supply is limited ($n < \beta$), a higher τ encourages greater investment in matching technologies, with positive spillovers that also stimulate demand in the traditional channel. Conversely, under abundant freight supply, the OFP's competitive position is strengthened, which diminishes its incentive to invest further and shifts demand away from traditional channels. Therefore, when cooperating with a platform that already possesses strong matching capabilities, additional efforts to boost acceptance may yield diminishing returns in terms of demand stimulation. In contrast, for OFPs with comparatively scarce freight capacity, initiatives that increase τ can effectively alleviate LSPs' utilization concerns, stimulate OFP-channel purchases, and support broader market expansion.

Corollary 5. Under Model R, the impacts of the OFP's capability and LSPs' characteristics on equilibrium demand are as follows:

(1) *Effect of unit freight revenue* f: i) If $n > \beta$ and $\tau > \tau_1$, $\frac{\partial d_t^{i*}}{\partial f} > 0$; otherwise, $\frac{\partial d_t^{i*}}{\partial f} < 0$; ii) $\frac{\partial d_o^{i*}}{\partial f} > 0$, $i \in \{P, M\}$.

(2) *Effects of freight resource* n *and LSP participation* β: i) $\frac{\partial d_t^{i*}}{\partial n} > 0$; $\frac{\partial d_t^{i*}}{\partial \beta} < 0$; ii) if $\tau > \tau_2$ and $f > f_2$, $\frac{\partial d_o^{i*}}{\partial n} > 0$; otherwise, d_o^{i*} first decrease and then increase with n; iii) if $\tau < \tau_3$ and $f < f_3$, or $\tau > \tau_3$ and $f > f_3$, $\frac{\partial d_o^{i*}}{\partial \beta} > 0$; otherwise, d_o^{i*} first decrease and then increase with β, $i \in \{P, M\}$.

Higher unit freight revenue (f) motivates the OFP to improve attractiveness via price cuts or matching upgrades, thus boosting demand. Particularly when freight supply is relatively limited or the reselling channel acceptance is low, the OFP's low-price strategy triggers the cannibalization effect, where rising unit freight revenue shifts demand from the traditional channel to the OFP. However, a higher freight supply-demand ratio ($\frac{n}{\beta}$) does not necessarily guarantee increased demand. Thus, in low-resource or low-acceptance scenarios, relying solely on price cuts is unsustainable for demand growth.

OFPs should instead augment the resale value of vehicles through integrated offerings such as financing packages, after-sales services, and technology-enabled matching upgrades. Manufacturers, in turn, should anticipate demand shifts across channels and avoid premature price increases or aggressive channel policies that could intensify conflict and undermine total system demand.

4. Effects of sales cooperation

In this section, we aim to answer the question of whether sales cooperation facilitates the penetration of NECV and brings benefits for both the manufacturer and the OFP.

Proposition 1. The online freight platform generates a positive sales spillover effect such that $d^{i*} > d^{N*}$, $\pi_M^{i*} > \pi_M^{N*}, \{i = T, A, P, M\}$.

Proposition 1 indicates that even in the absence of direct sales cooperation with the NECV manufacturer, the OFP creates significant economic value by functioning as an efficient transaction intermediary. The underlying mechanism operates as follows: By aggregating fragmented service demand and improving the efficiency of matching between service supply and demand, the OFP enhances the operational revenue and vehicle utilization rates of participating LSPs, thereby strengthening their incentives to purchase vehicles. This effect propagates upstream along the supply chain and ultimately materializes as increased vehicle demand and higher profits for the NECV manufacturer. The result confirms a positive synergy between the logistics service market and the NECV sales market.

Proposition 2. Effect of cooperation on matching investment and equilibrium demand.

(1) (*Platform operations effect*) i) $\lambda^{A*} < \lambda^{T*}$; ii) if $n > \beta$ and $f > f_4$, $\lambda^{i*} > \lambda^{T*}$; otherwise, $\lambda^{i*} < \lambda^{T*}$, $i \in \{P, M\}$.

(2) (*Market effect*) i) If $f < f_5$, $d^{A*} > d^{T*}$; otherwise, $d^{A*} < d^{T*}$; ii) $d^{i*} > d^{T*}$, $i \in \{P, M\}$.

Proposition 2 indicates that sales cooperation does not always motivate the OFP to enhance service capability or promote the market penetration of NECV. Under Model A, OFP tends to engage in free-riding behavior: it reduces long-term investment in matching efficiency and instead relies primarily on its existing traffic resources to monetize vehicle sales. Particularly when the unit service revenue is high, the demand for NECV under Model A may even contract.

In contrast, the reselling cooperation model demonstrates stronger synergistic potential. When OFP possesses a sufficient base of service demand and a substantial unit freight service revenue, Model R not only attracts more LSPs but also incentivizes OFP to increase investment in matching technologies. This occurs because OFP holds decision-making authority over both freight services and vehicle sales, enabling it to internalize the synergistic value between the service ecosystem and vehicle sales. OFP can employ a strategic combination of pricing and technology investment to maximize overall profits. As shown in Corollary 3, the OFP may effectively stimulate market demand through mechanisms such as purchase subsidies. In such cases, the market expansion effect can offset the negative impact of channel cannibalization, leading to an overall increase in demand.

Therefore, in a competitive market environment where the cooperating OFP possesses strong demand aggregation and service capabilities, manufacturers may achieve more effective market penetration for their own brand vehicles by ceding pricing authority through the reselling model rather than the agency model. This approach can better incentivize the OFP to act as a coordinator and fully leverage its integrative value.

Proposition 3. (*Profit effects*) Effects of sales cooperation on optimal profits.

(1) i) If $f < f_6$, $\theta < \theta_1$ and $a > a_1$, $\pi_M^{A*} > \pi_M^{T*}$; otherwise, $\pi_M^{A*} < \pi_M^{T*}$; ii) $\pi_{OFP}^{A*} > \pi_{OFP}^{T*}$.

(2) i) If $a > a_2$, $\pi_M^{i*} > \pi_M^{T*}$; otherwise, $\pi_M^{i*} < \pi_M^{T*}$; ii) $\pi_{OFP}^{i*} > \pi_{OFP}^{T*}$, $i \in \{P, M\}$.

Proposition 3 indicates that under Model A, the manufacturer's benefit depends on the alignment between the OFP's operational capability and the revenue-sharing ratio. An excessively high sharing rate can significantly erode the manufacturer's margins. A counterintuitive finding is that market expansion does not always translate into higher manufacturer profits. As illustrated in Figure 4, gains from demand expansion may be offset by the OFP's free-riding behavior, preventing the manufacturer from realizing actual profit growth.

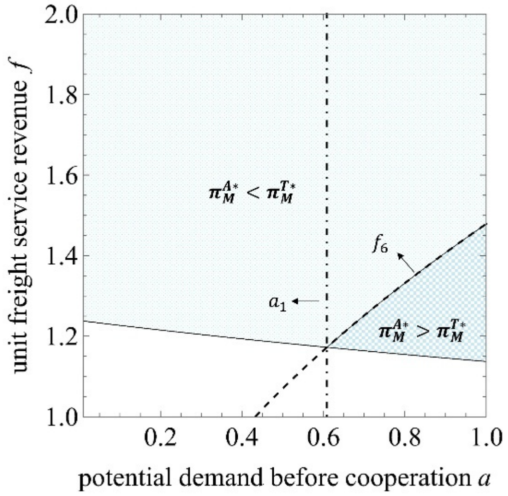


Figure 4. Comparisons of optimal profit between Model T and Model A ($n = 0.65, \beta = 0.85, \theta = 0.1$).

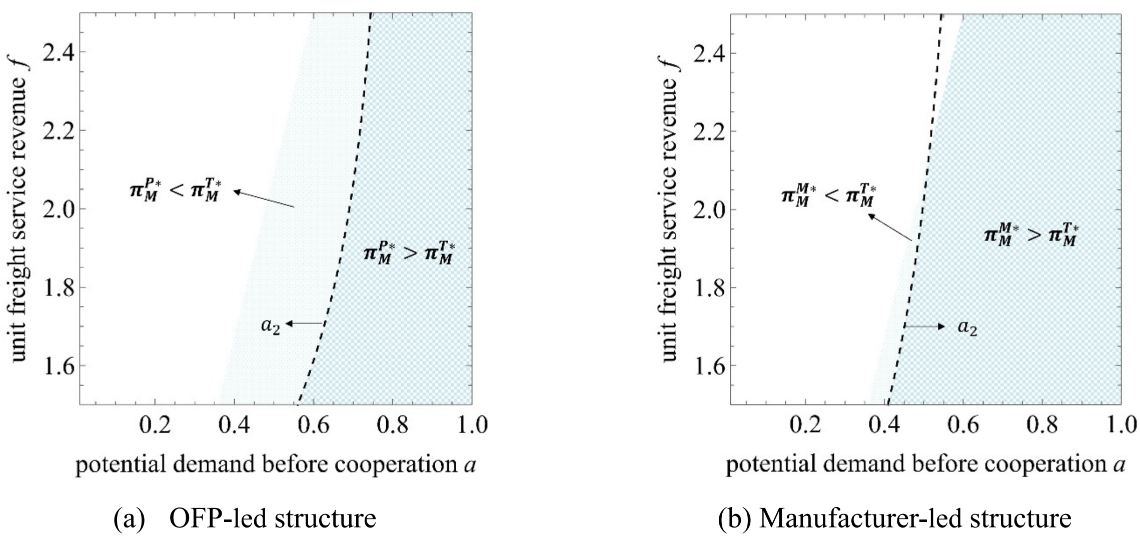


Figure 5. Comparison of optimal profit between Model T and Model R ($n = 0.65, \beta = 0.85, \theta = 0.1, \tau = 0.85$).

Under Model R, the manufacturer's profit improvement also has a clear boundary. This model outperforms the no-cooperation baseline only when the OFP's market expansion capability is relatively limited. When the OFP possesses strong access to potential customers, its enhanced bargaining power leads to aggressive low-price strategies that intensify inter-channel competition, erode demand in the manufacturer's sales channel, and ultimately reduce the manufacturer's overall profit. Hence, in markets where the OFP is highly capable, opting for no cooperation may emerge as the manufacturer's dominant strategy. In practice, as OFPs aggregate demand and suppress wholesale prices, some manufacturers advocate for de-platformization to regain pricing power. This reflects the underlying tension between sales growth and profit maximization. As shown in Figure 5, increased sales can also saturate the platform's freight capacity, reducing service quality and LSP engagement, thereby limiting the scale economies from cooperation.

Conversely, for the OFP, both agency and reselling cooperation create complementary revenue streams, thus enhancing overall profitability.

5. Selection of a cooperation strategy

We next compare the equilibrium outcomes under Model A and Model R. We are interested in the optimal cooperation strategy preferences of the manufacturer and the OFP when considering different internal operational factors and external market circumstances.

Proposition 4. Effect of cooperation models on matching investment and equilibrium demand.

(1) If $n > \beta$ or $a < a_3$, $\lambda^{i*} > \lambda^{A*}$; otherwise, $\lambda^{i*} < \lambda^{A*}$, $i \in \{P, M\}$.

(2) $d^{i*} > d^{A*}$, $i \in \{P, M\}$.

While proposition 2 suggests that agency cooperation weakens the OFP's incentive to invest in matching capabilities due to free-riding, this does not imply that reselling necessarily yields superior service investment. When LSPs are highly dependent on the OFP, and the OFP exhibits strong sales potential, limited freight availability may prompt the OFP to adopt aggressive pricing strategies to boost NECV sales. To maintain the low resale margin, the OFP further reduces investment in matching capabilities. In this case, high LSP reliance leads the OFP to prioritize short-term price competition over long-term service enhancement.

Nevertheless, the introduction of a reselling channel consistently outperforms pure agency in expanding total market demand. Under Model R, the OFP and the NECV manufacturer jointly coordinate pricing and service decisions, enhancing LSPs' purchase incentives. The OFP's flexibility in adjusting vehicle prices according to market conditions enables better synergy between freight services and vehicle sales, driving market growth.

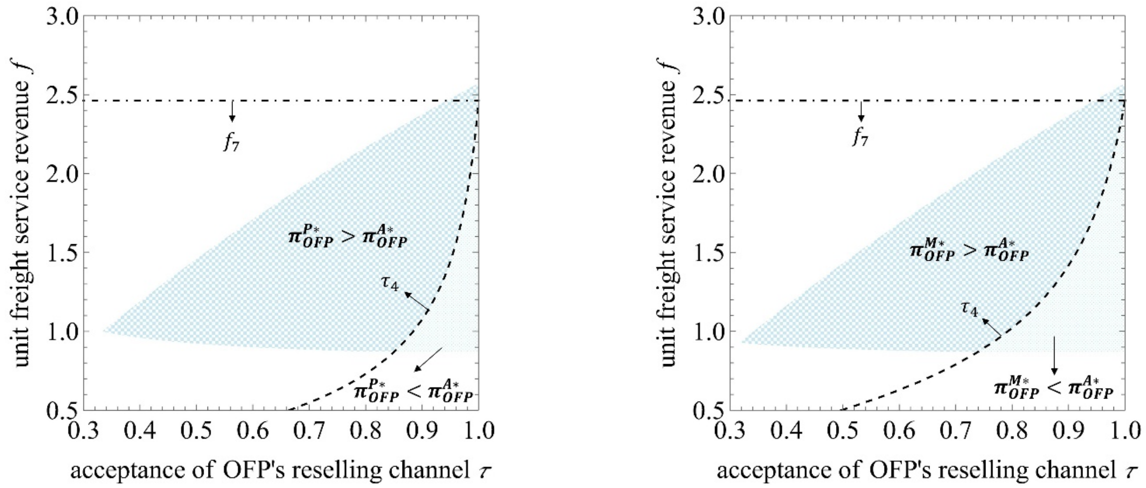
Proposition 5. Effect of different cooperation models on optimal profits.

(1) $\pi_M^{i*} > \pi_M^{A*}$, $i \in \{P, M\}$;

(2) If $f < f_7$ and $\tau > \tau_4$, $\pi_{OFP}^{i*} < \pi_{OFP}^{A*}$; otherwise, $\pi_{OFP}^{i*} > \pi_{OFP}^{A*}$, $i \in \{P, M\}$.

Unlike Wang et al. [59] and Mao et al. [12], who found that manufacturers prefer agency models at low commission rates, our results show contrasting findings. In our setting, the OFP plays a dual role in both vehicle sales and freight service provision under Model R, enabling broader market coverage and higher profitability. In contrast, under Model A, the OFP only shares revenue from vehicle sales and lacks direct responsibility for promotion, which weakens its incentive to invest in freight-side capabilities, resulting in lower service quality and reduced LSP engagement.

Interestingly, diverging from Chen et al. [15], who argued that the reselling model is generally more profitable for the platform due to greater control over sales, we find that the OFP's preference critically depends on the intensity of inter-channel competition and its competitive advantage (see Figure 6). When LSPs strongly favor platform reselling, competition between the OFP and the manufacturer intensifies. Consistent with Abhishek et al. [21], the manufacturer may adopt aggressive pricing to retain demand, significantly compressing the platform's resale margins. Under limited freight revenue and resale profits, OFP's profitability is constrained. In contrast, the agency model shields the OFP from direct pricing pressure while benefiting from increased vehicle sales via exposure-based incentives, securing relatively higher profits.



(a) OFP-led structure (b) Manufacturer-led structure

Figure 6. Comparisons of optimal profits between Model A and Model R ($n = 0.5, \beta = 0.6, \theta = 0.1, a = 0.6$).

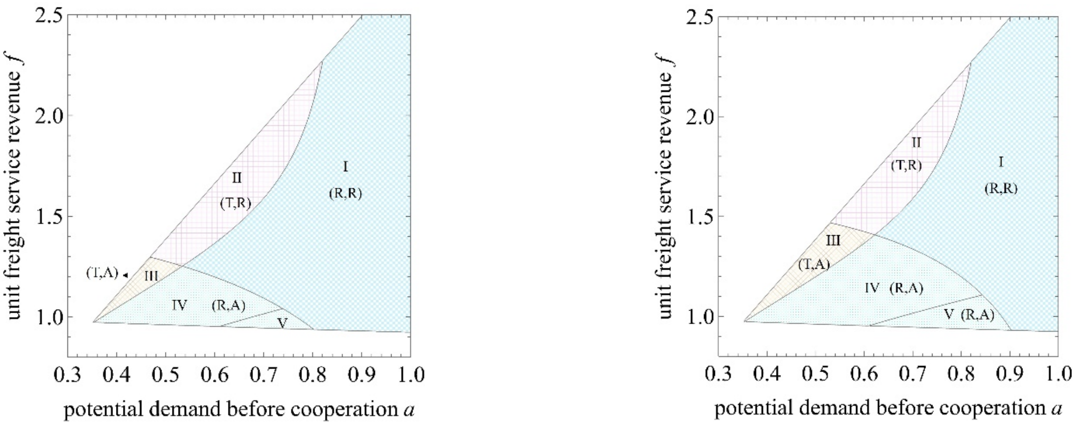
5.1. Strategy alignments between the manufacturer and online freight platform

The above analysis outlines the distinct strategic preferences between the manufacturer and the OFP. When the manufacturer selects the cooperation mode, the reselling strategy emerges in equilibrium if $a > a_2$; otherwise, non-cooperation is preferred. When the OFP makes the choice, Model A constitutes the equilibrium if $f < f_7$ and $\tau > \tau_4$, whereas Model R is selected otherwise. A sustained partnership, however, depends on the attainment of mutually beneficial outcomes. We therefore extend the analysis to examine how the OFP's core capabilities, specifically, its market expansion potential and unit freight revenue, shape the alignment or divergence of their strategic preferences.

Corollary 6. Strategic alignment between the NECV manufacturer and the OFP is limited, and the prisoner's dilemma would be triggered without compromise.

Figure 7 illustrates preference distributions and corresponding equilibria. Stable cooperation emerges only in Region I, where both of them prefer the reselling model. Here, moderate freight profitability and limited market expansion potential help align platform incentives with manufacturer's pricing power. In Regions II and III, the OFP benefits from strong freight revenue or broad market reach and thus prefers cooperation, but the manufacturer, facing reduced margins or pricing power, may opt out. In contrast, in Regions IV and V, the manufacturer prefers reselling, while the OFP favors agency due to low freight-side returns. Especially in Region IV, the absence of compromise leads to a prisoner's dilemma, where both sides are worse off under non-cooperation.

Nonetheless, moderate compromise can improve outcomes, as summarized in Table 4. To facilitate alignment, firms may adopt targeted concessions such as resale price guarantees or bundled value-added services. Moreover, forming deeper strategic alliances can enhance mutual gains. A case in point is the partnership between Shengsheng Freight and Shineray Auto, which leveraged freight data to co-develop the Shineray E3L for urban delivery[1].



(a) OFP-led structure (b) Manufacturer-led structure

Figure 7. Model preferences of the manufacturer and OFP ($\beta = 0.85, n = 0.8, \theta = 0.1, \tau = 0.95$). Note: Strategy (i, j) represents when the manufacturer prefers Model i, while the OFP prefers Model j, $i, j \in \{T, R, A\}$.

Table 4. Improved equilibrium strategies.

Region	Improved strategy	Rationale
II	OFP value concession → Reselling model	Prevents equilibrium shift to suboptimal outcome "non-cooperation".
III	OFP value concession → Reselling model	Avoids suboptimal "non-cooperation" strategy.
IV	Negotiated compromise → Reselling model or agency model	"Non-cooperation" is a strictly dominated strategy for both parties.
V	OFP value concession → Reselling model	Avoids suboptimal "non-cooperation" strategy.

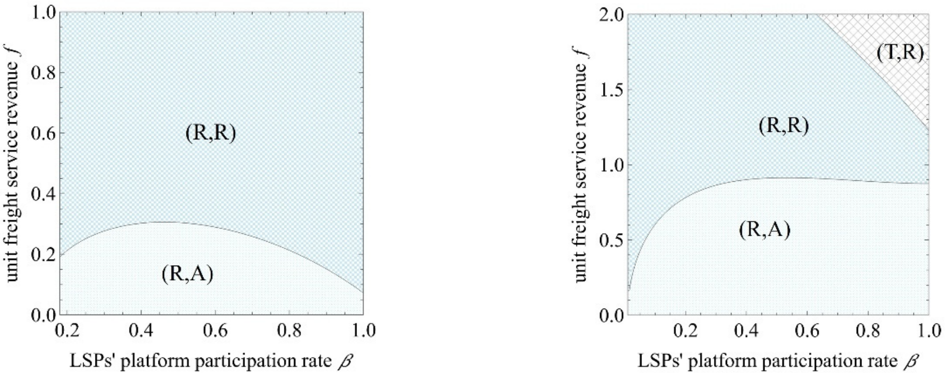
5.2. Effects of LSPs' characteristics on strategy preferences of manufacturer and OFP

Building on the previous analysis of platform capabilities, we further explore how heterogeneity among LSPs affects cooperation dynamics. Specifically, we examine two key LSP-related parameters:

[1] https://www.toutiao.com/article/7348371266098840064/

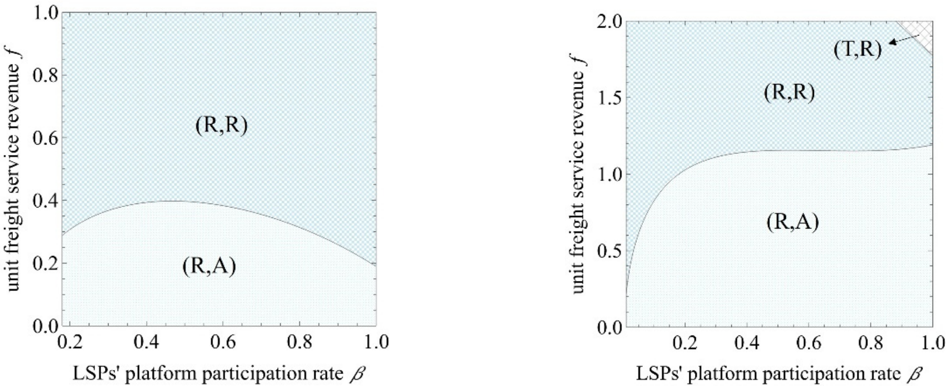
dependence on platform freight supply (β) and acceptance of platform reselling (τ). Figures 8 and 9 illustrate how variations in these parameters reshape the strategic equilibrium.

For the manufacturer, a higher τ intensifies channel competition and weakens pricing power, especially when β is high. In such cases, non-cooperation may be preferable to avoid further margin erosion. In contrast, for the OFP, an increase in τ enhances the appeal of agency cooperation, as it enables the OFP to benefit from vehicle exposure without incurring competitive risk. Reselling becomes attractive only when β is sufficiently high to generate adequate freight-side revenue, which can offset pricing pressure. In this context, freight revenue acts as a buffer, making reselling viable under strong downstream engagement.



(a) $\tau = 0.35$ (b) $\tau = 0.9$

Figure 8. Effects of LSP's characteristics (β, τ) on strategy preferences in Model P.



(a) $\tau = 0.35$ (b) $\tau = 0.9$

Figure 9. Effects of LSP's characteristics (β, τ) on strategy preferences in Model M.

Our analysis reveals that when LSPs perceive higher value in purchasing vehicles through the OFP, the alignment of strategic preferences between the manufacturer and OFP becomes increasingly difficult to achieve, as shown in Figure 10. In particular, as the LSPs' reliance on the platform for freight supply (i.e., a higher β) increases, the manufacturer is more likely to deviate from cooperation strategies and favor non-cooperation. This strategic shift is rooted in the growing channel power of the OFP. While the OFP gains influence through enhanced downstream engagement, the manufacturer faces increasing margin pressure due to reduced control over pricing and the market. Consequently, the manufacturer cannot rely solely on the promotional spillover effects generated by the OFP. Instead, it must focus on strengthening its proprietary sales channel by investing in differentiated value propositions, such as high-quality after-sales service and flexible financing options.

Moreover, a high level of freight-side dependence (i.e., a large β) often signals a sluggish private freight market, in which LSPs struggle to secure demand through the contract market. In such environments, LSPs become structurally tied to the OFP for business continuity. If the manufacturer has already entered a reselling partnership with the OFP under these conditions, it becomes even more critical to reinforce the competitiveness of its own sales channel. Otherwise, the manufacturer risks becoming overly dependent on the OFP's intermediary role, which may erode its brand positioning, pricing flexibility, and long-term strategic autonomy.

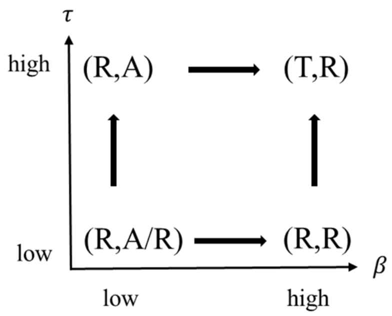


Figure 10. Strategy transfers in changes of β and τ.

5.3. Environmental impacts

5.3.1. Environmental benefits during the transportation phase

As the volume of NECVs deployed in the market increases, they gain greater access to freight opportunities, making environmental benefits positively correlated with vehicle adoption. Let e_t denote the per-unit environmental benefit during the transportation phase. The total environmental benefit (EB) under channel model $j \in \{T, A, P, M\}$ can thus be expressed as $EB^j = e_t d^{j*}$. According to Propositions 2 and 4, the reselling cooperation model can generate the highest environmental benefits in the transportation phase because of the highest market penetration.

5.3.2. Lifecycle environmental impact

Recent debates highlight that the carbon emissions associated with manufacturing an NECV may exceed those of producing a conventional fuel vehicle[2]. Therefore, a comprehensive evaluation of the environmental benefits of NECVs must account for emissions from both the production and operational phases. To facilitate tractable analysis, we assume $\beta = 1$, meaning all LSPs obtain freight demand through the OFP. Let e_p represent the relative environmental cost incurred during the

[2] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-race-to-decarbonize-electric-vehicle-batteries

production phase of NECVs. We define $\delta = \frac{e_p}{e_t}$ as the relative environmental impact of production, capturing the trade-off between production emissions and operational environmental gains.

(1) Freight service supply-driven market

In markets characterized by abundant freight service capacity, vehicle sales are assumed to be positively correlated with the available service capacity, expressed as ρd^{i*}, where $0 < \rho < 1$. Under this condition, the total environmental benefits (EB) from adopting NECVs can be expressed as $EB^j = e_t(\rho d^{j*} + \lambda^{j*} n) - e_p d^{j*}$, let $\psi^{jk} = n\frac{\lambda^{j*} - \lambda^{k*}}{d^{j*} - d^{k*}}$, $\{j, k \in \{T, A, P, M\}\}$.

Proposition 6. When $\delta < \min\{\rho + \psi^{iT}, \rho + \psi^{iA}\}$, Model R becomes environmentally preferable; when $f < f_5$ and $\rho + \psi^{iA} < \delta < \rho + \psi^{AT}$, or $f > f_5$ and $\delta > \max\{\rho + \psi^{AT}, \rho + \psi^{iA}\}$, Model A yields superior environmental performance. Otherwise, the non-cooperation scenario delivers the highest environmental benefit.

According to Proposition 6, when production-phase emissions are relatively low, Model R enhances environmental benefits by increasing NECV penetration and improving vehicle utilization. In contrast, Model A is more sensitive to vehicle demand and production emissions. When production emissions are high, the environmental gains from greater usage are offset by overproduction. Only under moderate demand and improved matching efficiency does agency cooperation outperform. Otherwise, reduced output under lower vehicle demand may offer superior environmental benefits.

(2) Freight service demand-driven market

In the scenario where freight service capacity exceeds service demand, the realized freight volume is constrained by demand rather than capacity. Let the freight demand from the private market be $R(R > 0)$, then the total freight demand is $R + \lambda^{i*} n$. Under this setting, the environmental benefit (EB) is characterized as $EB^j = e_t(R + \lambda^{j*} n) - e_p d^{j*}$, $\{j \in \{T, A, P, M\}\}$.

Proposition 7. When $f > f_5$ and $\delta > \psi^{AT}$, Model A yields the highest environmental benefit; otherwise, cooperation cannot enhance environmental performance.

In a saturated market, Model A may improve environmental outcomes, primarily by curbing vehicle production. In contrast, Model R risks overproduction and low vehicle utilization, leading to higher lifecycle emissions. These insights caution against indiscriminate NECV adoption. Instead, manufacturers should focus on low-carbon production, and policymakers should prioritize targeted scrappage incentives over expansion subsidies to align market growth with environmental objectives and avoid resource misallocation.

6. Effects of power structures

In this section, based on the different market positions of the OFP, we compare the two different power structures, exploring the effects on equilibrium decisions.

Proposition 8. Effect of power structures on equilibrium matching investment and demand.

$m_o^{M*} < m_o^{P*}$, $d_o^{M*} < d_o^{P*}$; if $n \leq \beta$, $\lambda^{M*} > \lambda^{P*}$, $p_t^{M*} > p_t^{P*}$, $p_o^{M*} > p_o^{P*}$, $d^{M*} > d^{P*}$, $d_t^{M*} > d_t^{P*}$; otherwise, $\lambda^{M*} < \lambda^{P*}$, $p_t^{M*} < p_t^{P*}$, $p_o^{M*} < p_o^{P*}$, $d^{M*} < d^{P*}$, $d_t^{M*} < d_t^{P*}$.

Proposition 8 underscores the importance of aligning channel power with platform capabilities. With platform-limited freight supply, the manufacturer-led structure can trigger a "disciplinary mechanism", which curbs opportunistic pricing and supports market expansion. Conversely, when the OFP has strong freight aggregation power, shifting to a platform-dominated reselling model becomes more effective. Granting the manufacturer greater autonomy can incentivize investment in matching technologies, optimize pricing, and integrate freight services with vehicle sales. Empowering the OFP under such conditions allows the manufacturer to better leverage its strengths to drive demand and improve sales outcomes.

Proposition 9. Effect of power structures on optimal profits.

(1) If $f > f_8$, or $\beta > \frac{(\sqrt{5}-1)n}{2}$ and $\tau > \max\{\tau_5, \underline{\tau}\}$, $\pi_M^{M*} > \pi_M^{P*}$; otherwise, $\pi_M^{M*} < \pi_M^{P*}$.

(2) $\pi_{OFP}^{M*} < \pi_{OFP}^{P*}$.

Proposition 9 highlights that a manufacturer-led structure is preferable when unit freight revenue, LSPs' freight dependence, and reselling acceptance exceed critical thresholds. When freight-side value is strong but sales spillovers are limited, retaining pricing power helps the manufacturer preserve margins amid channel competition. According to Proposition 7, with strong freight supply and market influence, a platform-led reselling model may be more effective in boosting sales. However, this can erode manufacturer profitability through suppressed wholesale prices, underscoring the trade-off between control and market expansion. As shown in Figure 11, manufacturers must carefully consider strategic priorities and adopt measures to mitigate such conflicts. For instance, when facing issues like excessive vehicle inventory, manufacturers should prioritize ceding decision-making authority to lower unsold inventory risk; by contrast, when profit margins are strained, or the platform's sales channel is highly competitive, they should seek to retain decision-making dominance.

From the OFP's view, retaining dominance yields higher returns. Limited freight supply drives up markups and discourages investment in matching technologies. In contrast, an abundant supply incentivizes service investments to attract LSPs and boost long-term revenue. However, this preference may conflict with the manufacturer's goals. When freight resources are tight, OFPs should consider making concessions to sustain cooperation and unlock joint value.

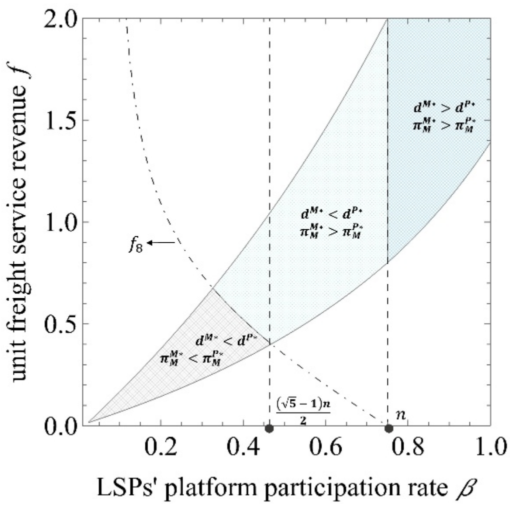


Figure 11. Effects of power structures on the equilibrium demand and optimal profits.

7. Conclusions

OFPs have become important intermediaries in freight markets by aggregating fragmented freight demand, improving matching efficiency, and enhancing vehicle utilization. These operational improvements increase the economic attractiveness of NECVs for LSPs, thereby creating a usage-driven demand mechanism that links freight services with vehicle adoption. Motivated by this emerging industry practice, this study investigates strategic sales cooperation between an NECV manufacturer and an OFP under agency and reselling cooperation modes and alternative channel power structures.

Our analysis generates several important findings. First, we show that OFPs can stimulate NECV adoption not only by expanding product exposure but also by improving freight-side operational profitability. However, cooperation does not always improve system performance. Under the agency model, the OFP may exhibit free-riding behavior by relying on shared sales revenue while underinvesting in matching capability, especially when freight-side profitability is already high. In contrast, the reselling model creates stronger incentive alignment between vehicle sales and service investment, thereby generating greater market expansion potential. Nevertheless, when freight resources or freight-side profitability are limited, the OFP may prioritize aggressive price discounts over service investment, which intensifies competition and erodes manufacturer profits. These results reveal an important trade-off between market expansion and profitability in NECV promotion. Second, the strategic preferences of the manufacturer and the OFP are not always aligned. The manufacturer generally favors the reselling model because it better coordinates vehicle sales and freight service incentives. However, the OFP's preference depends on freight-side profitability and channel acceptance. Under unfavorable market conditions, a prisoner's dilemma may emerge, preventing both parties from achieving mutually beneficial outcomes. Moreover, our environmental analysis suggests that increased NECV adoption does not automatically guarantee lifecycle sustainability. Although cooperation can improve utilization efficiency and reduce operational emissions, production-phase emissions may offset these benefits if cleaner manufacturing technologies are not simultaneously adopted. Third, power structure significantly shapes equilibrium outcomes. When the OFP possesses abundant freight resources, platform-led structures encourage stronger service investment and broader market expansion. By contrast, when LSPs rely heavily on the OFP for freight access, manufacturer-led structures can mitigate opportunistic platform behavior and improve coordination efficiency. Differently, the manufacturer's preference for channel control is context-dependent and does not necessarily align with the objective of maximizing market coverage. Our analysis reveals that when both freight supply and unit freight revenue are substantial, the manufacturer tends to hold the prioritized pricing power, thereby avoiding the profit erosion from intensified competition.

Based on the above analysis, we derive several managerial insights. First, manufacturers should align cooperation modes with platform capabilities and strategic objectives. When the goal is rapid market expansion or overcapacity reduction, reselling cooperation is more effective because it better aligns the OFP's incentives with vehicle promotion and freight-service improvement. However, when platforms possess strong market power but limited operational commitment, agency cooperation may help reduce dependence and mitigate channel conflict. In addition, manufacturers should strengthen their own digital freight-service capabilities to maintain bargaining power and strategic flexibility. Second, for OFPs, long-term competitiveness depends not only on expanding vehicle sales but also on improving freight matching efficiency and service quality. Our findings suggest that excessive price competition may weaken profitability and reduce incentives for service investment, especially under limited freight supply. Therefore, OFPs should prioritize investments in matching technologies and freight resource integration, while adopting coordination mechanisms such as transparent pricing or performance-based commissions to improve cooperation stability. Third, from a policy perspective, promoting NECV adoption requires coordinated support for both vehicle diffusion and freight-service efficiency. For NECV categories with high production-phase emissions, subsidizing OFPs' matching capability construction and freight-service digitalization may generate greater lifecycle environmental benefits than relying solely on vehicle purchase subsidies. Policymakers may also consider performance-based incentives linked to vehicle utilization and operational efficiency to encourage sustainable adoption.

Future research may extend this study along several dimensions. First, we assume a uniform distribution of LSP heterogeneity for analytical tractability. Future studies may consider alternative right-skewed distributions, such as beta or lognormal distributions, to better capture the characteristics of freight markets. Second, this study adopts a static game-theoretic framework and does not explicitly model repeated interactions, adaptive learning, or long-term coordination processes between manufacturers and OFPs. Future research may incorporate evolutionary or repeated-game dynamics, as well as explicit coordination mechanisms such as side-payment contracts or negotiated commissions, to further investigate long-term cooperation stability and strategic adaptation in freight-platform ecosystems [60,61]. Finally, incorporating product heterogeneity, such as competition between conventional fuel vehicles and NECVs, may further deepen understanding of sustainable freight transition strategies.

Author contributions

Jing Xu: conceptualization, writing-original draft; Nengmin Wang: funding acquisition, supervision; Bin Wei: writing-review & editing; Bin Jiang: supervision.

Use of Generative-AI tools declaration

During the preparation of this manuscript, the authors used ChatGPT for language polishing and expression improvement. All AI-assisted content was critically reviewed and revised by the authors, who take full responsibility for the final published version.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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