

Commission and traffic support under demand uncertainty in a dual-channel supply chain

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Research Article

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Abstract

Digital platforms determine both the share of transaction value they retain and the visibility allocated to sellers. This study examines the joint choice of a proportional commission rate and verifiable traffic-support investment in a dual-channel supply chain under ex ante demand uncertainty. A manufacturer sells through an agency platform and an offline retailer. The platform commits to commission and support before demand is realized, while downstream prices adjust after the demand state becomes observable. The model is a constrained stochastic Stackelberg game with manufacturer participation, positive-demand conditions, and consumer surplus derived from a common utility system. The analysis establishes a commission-traffic feedback mechanism. A higher commission improves the platform's direct return from support-generated transactions, but the manufacturer's pricing response and the associated reduction in online volume work in the opposite direction. Commission and support are complementary when the direct monetization effect is stronger than the induced pricing-volume response. At a fixed commission, additive demand variance does not directly change the interior support condition. With endogenous commission, uncertainty affects support through the commission response and can produce nonmonotonic policy adjustments near feasibility boundaries. Two closed-form spillover thresholds separate online migration, simultaneous expansion of both channels, and offline expansion accompanied by online contraction. The welfare effect of a commission cap contains a direct pricing-surplus component and an endogenous support component, so lower commissions do not always improve welfare. Scenario-based numerical results show a material gap between the platform-optimal and welfare-oriented policies and identify a moderate manufacturer cost-sharing interval that benefits several stakeholders. The findings explain how value extraction, demand generation, channel conflict, and regulation interact in platform supply chains.

Keywords: platform governance, agency selling, commission rate, traffic support, dual-channel supply chain, demand uncertainty, channel migration

1. Introduction

Digital platforms govern the division of transaction value and the visibility received by sellers. Search ranking, recommendation, promotion, featured display, and campaign access determine how much consumer attention reaches a merchant. The commission rate and traffic support are therefore related operational decisions. Commission determines the platform's revenue from each completed online sale, while traffic support affects the number of transactions on which commission is earned. This connection is observed in marketplaces, food-delivery services, content platforms, and live-streaming channels, where fee arrangements are often linked to exposure or service intensity [1-5].

The main economic issue is how the platform's take rate changes its willingness to generate demand. A higher commission increases revenue per online sale and can strengthen the return to traffic support. It also reduces the manufacturer's retained online margin, which may lead to a higher online price, lower online volume, channel reallocation, or rejection of the agency contract. Traffic support may benefit the offline channel through brand awareness or reduce offline demand through channel migration. The platform must balance monetization, downstream pricing responses, and cross-channel effects. Demand uncertainty makes this interaction more important. Fee schedules and major traffic commitments are often determined before

the market state is known, while sellers can adjust prices after demand conditions become visible. This timing gives downstream firms an option to adapt prices across states and changes the expected transaction base faced by the platform. A mean-zero additive shock does not necessarily enter the interior support condition when commission is fixed. Its effect can operate through the commission chosen by the platform. The model therefore solves commission and support jointly and specifies the order of decisions explicitly.

The related literature studies each part of this problem but does not fully characterize the feedback between the two platform instruments. Agency-selling research examines marketplace and reselling formats, seller pricing, and endogenous fees [6-9]. Research on platform investment and discoverability considers service provision, promotion, ranking, and traffic allocation [2,3,10-12]. Welfare and regulation studies show that platform fees affect participation, quality, prices, and consumer surplus [13-17]. A fixed-commission model cannot determine how the take rate changes support incentives. A fixed-support model cannot evaluate commission regulation after the platform adjusts demand generation. The analysis focuses on four issues. It identifies the conditions under which a higher commission strengthens the platform's marginal incentive to provide traffic support. It traces the effect of ex ante demand uncertainty on support when downstream prices are state contingent. It separates market expansion from migration between online and offline channels. It also evaluates commission caps and cooperative cost sharing when the platform is allowed to reoptimize support.

We develop a platform-led stochastic Stackelberg game with one manufacturer, one offline retailer, and one agency platform. The platform first offers a commission-support pair, after which the manufacturer accepts or rejects the agency channel. Conditional on acceptance, the demand state is publicly observed, the manufacturer sets its online and wholesale prices, and the retailer then chooses the offline price. A quadratic representative-consumer utility yields internally consistent online and offline demands and consumer surplus. The manufacturer participation constraint, support capacity, commission bound, positive-demand conditions, and channel-exit boundaries are incorporated into the platform problem rather than checked only after an interior solution is obtained.

The paper contributes to platform and dual-channel operations research in three respects. The main theoretical contribution is a commission-traffic cross-incentive mechanism that separates the direct monetization effect from the opposing pricing-volume response. This result provides a testable condition for complementarity instead of assuming that commission and support move in the same direction. A second contribution is the commission-mediated transmission of demand uncertainty. Additive variance has no direct effect on the fixed-commission interior support condition, but it changes support through the commission response when both instruments are endogenous. The third contribution is a pair of closed-form spillover thresholds that distinguish online migration, simultaneous channel expansion, and offline expansion with online contraction. The regulatory analysis then decomposes the welfare effect of a commission cap and identifies a moderate cost-sharing range in which several stakeholder outcomes improve.

2. Literature Review

2.1 Agency selling and endogenous commission

Platform research emphasizes that governance choices determine participation, pricing, value creation, and value capture in multisided markets [18-23,45,48]. In electronic retailing, agency selling assigns retail-price control to the supplier while the platform receives a proportional share of sales. This structure differs fundamentally from wholesale reselling because the commission directly enters the supplier's retained margin and therefore changes both pricing and participation incentives [6,7,24,25,47].

Recent work moves beyond treating the fee as an exogenous contract parameter. Research examines endogenous commission, fee discrimination, referral fees, commission menus, platform disintermediation, seller heterogeneity, financing, and regulation [4,8,9,13,16,26-28,46]. These studies establish that the highest feasible fee is generally not optimal once seller behavior and market participation respond. Our analysis treats commission as one component of a two-instrument governance problem in which the fee also changes the platform's return to traffic support.

2.2 Platform traffic-support and service investment

Platforms create demand through service investment, discoverability, ancillary seller services, promotion, search design, and traffic allocation. Such investments can improve conversion and seller reach but may also crowd out seller investment, redistribute demand, or create spillovers that the platform cannot fully monetize [2,10,29,30]. Recent marketplace research makes visibility more explicit by studying promotion, discoverability, featured display, recommendation, and traffic channeling [3-5,11,12].

The existing literature typically takes the commission schedule as given when optimizing traffic or service, or takes service intensity as given when optimizing the fee. This separation is analytically convenient but suppresses the feedback at the center of platform governance: a higher take rate changes the marginal revenue generated by each additional unit of support, while support-induced demand changes the feasible and profitable commission. We model a continuous committed support level, allow its direct offline effect to be positive or negative, and solve the commission-support pair jointly.

2.3 Dual-channel competition and demand uncertainty

Dual-channel supply chains combine vertical pricing with horizontal substitution. Foundational studies show that direct and retail channels can discipline each other while generating channel conflict and coordination opportunities [31,32]. Platform-based extensions examine channel selection, secondary marketplaces, cross-channel effects, platform financing, and alternative selling modes [27,33-37]. Our distinction between channel substitutability and the direct offline traffic effect prevents support-induced brand spillover from being conflated with price-mediated substitution.

Demand uncertainty enters platform and supply-chain models through inventory, private information, forecasting, conversion uncertainty, or state-contingent decisions [12,38-41]. The main model deliberately excludes private information: demand is uncertain when the platform commits, but the realized state becomes common information before downstream pricing. This timing isolates the value of price adaptation and reveals a commission-mediated uncertainty channel without mixing it with information rents or disclosure incentives.

2.4 Consumer welfare, regulation, and research positioning

The platform-welfare literature warns that private platform objectives need not align with consumer or system outcomes. Proportional fees, platform quality, seller participation, price control, and first-party applications can each create a wedge between platform profit and welfare [13-15,42-44]. Recent studies of retailer-led marketplaces, service-platform regulation, and restaurant-platform contracts further show that fee restrictions or revenue-sharing reforms must be evaluated together with endogenous operational responses [4,16,17].

Our regulatory analysis follows this principle. A commission cap constrains the platform's fee but leaves it free to reoptimize traffic support. Welfare is therefore evaluated along the platform's endogenous support response rather than under a fixed-investment counterfactual. We also distinguish a centralized-profit benchmark, in which commission is an internal transfer, from the decentralized policy problem, in which firms continue to price strategically. This distinction prevents a supply-chain coordination benchmark from being mislabeled as a regulator's welfare optimum.

2.5 Research gap and positioning

The gap in the literature concerns the mechanism connecting commission, investment, uncertainty, and welfare. A fixed-commission model cannot determine whether a higher take rate raises the return to support. A fixed-support model cannot evaluate a fee restriction after the platform changes seller exposure. A model without explicit timing cannot separate a direct variance effect from the response transmitted through commission. This study addresses these limitations through the commission-traffic cross-incentive, the uncertainty-transmission decomposition, and two analytical channel-demand thresholds. Table 1 summarizes the positioning.

Table 1. Literature positioning matrix

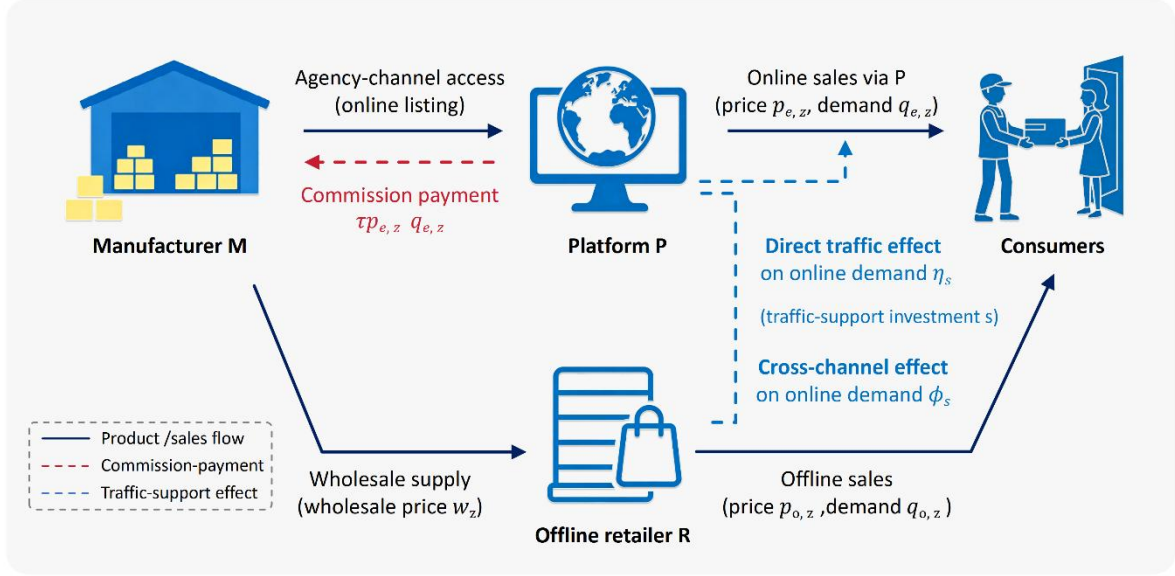
Study	Endogenous commission	Platform investment/traffic	Channel setting	Demand uncertainty	Consumer/social welfare
Abhishek et al. [6]	No	No	Agency vs. reselling	No	Limited
Hu et al. [8]	No	No	Agency vs. wholesale	No	Consumer-price implications
Zhang et al. [10]	No	Service investment	Platform + supplier direct channel	No	Firm profits
Yu et al. [12]	No	Traffic allocation	Competing merchants	Conversion uncertainty	Merchant/platform welfare
Cheng et al. [3]	Commission parameter	Promotion effort	Online marketplace	No	Platform and sellers
Oh et al. [4]	Commission menu	Featured display + delivery	Restaurant platform	Market heterogeneity	Coordination and total profit
Hervas-Drane and Shelegia [16]	Yes	Consumer steering	Retailer-led marketplace	No	Fee regulation
Xia et al. [5]	Service-rate interaction	Traffic support	Dual live-streaming channels	No	Consumer surplus
This study	Yes	Endogenous traffic support	Online agency + offline retail	Ex ante demand states	CS, SW, regulation

3. Model Setup

3.1 Supply-chain structure and decision timeline

The supply chain contains a manufacturer M , an offline retailer R , and an e-commerce platform P . The manufacturer sells the same product through two channels. In the online agency channel, the manufacturer chooses the retail price $p_{e,z}$ and retains a fraction $1 - \tau$ of sales revenue, the platform receives commission rate τ . In the offline channel, the manufacturer charges wholesale price w_z and the retailer chooses price $p_{o,z}$. The subscript $z \in \{H, L\}$ denotes the demand state. The platform chooses traffic-support investment s subject to a finite operational capacity $0 \leq s \leq s_{\max}$. Support represents verifiable recommendation exposure, search-priority improvement, campaign placement, and related traffic operations, it is not physical transportation investment. The platform incurs the convex real resource cost $ks^2/2$, where $k > 0$. The support commitment is contract contingent: it is deployed, and its cost is incurred, only after the manufacturer accepts the agency contract. The decision timeline is shown in Figure 1. First, the platform offers a contract (τ, s) , where $0 \leq \tau \leq \tau_{\max} < 1$ and $0 \leq s \leq s_{\max}$. Second, the manufacturer accepts or rejects the agency channel. Rejection leads to the offline-only outside option, Model O. Third, after acceptance, the platform deploys the committed support. Fourth, demand state z becomes common information. Fifth, the manufacturer simultaneously sets $p_{e,z}$ and w_z . Sixth, the retailer observes these decisions and sets $p_{o,z}$.

(a)



(b)

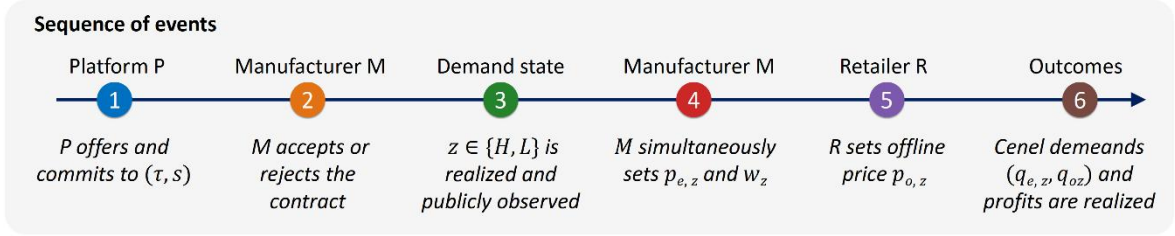


Figure 1. Supply-chain structure and six-stage sequence of events. The platform offers and commits to the commission-support pair before participation and demand realization, support is deployed and its cost is incurred only after acceptance, while downstream prices are state contingent.

3.2 Consumer utility and channel demands

Let A_z denote market potential in state z , and let $\alpha \in (0,1)$ denote baseline online preference. A representative consumer's gross utility from channel quantities $q_{e,z}$ and $q_{o,z}$ is

$$U_z = (\alpha A_z + \eta s)q_{e,z} + [(1 - \alpha)A_z + \phi s]q_{o,z} - \frac{1}{2}(q_{e,z}^2 + q_{o,z}^2 + 2\mu q_{e,z}q_{o,z}) - p_{e,z}q_{e,z} - p_{o,z}q_{o,z} \quad (1)$$

Here $\eta > 0$ is the online conversion efficiency of traffic support, $0 \leq \mu < 1$ is channel substitutability, and ϕ is the direct cross-channel traffic effect. A positive ϕ captures brand-awareness spillover to offline demand, $\phi = 0$ means traffic support affects only the online intercept, and $\phi < 0$ captures direct demand migration away from the offline channel. This direct effect is distinct from substitution induced by relative prices, which is already represented by μ . Maximizing (1) with respect to channel quantities gives

$$q_{e,z} = \frac{\alpha A_z + \eta s - p_{e,z} - \mu[(1 - \alpha)A_z + \phi s - p_{o,z}]}{1 - \mu^2} \quad (2)$$

$$q_{o,z} = \frac{(1 - \alpha)A_z + \phi s - p_{o,z} - \mu[\alpha A_z + \eta s - p_{e,z}]}{1 - \mu^2} \quad (3)$$

The main analysis focuses on an interior dual-channel region in which both quantities are positive in both demand states. Boundary cases can be solved using Kuhn-Tucker conditions and are included in numerical feasibility checks.

3.3 Demand uncertainty

Demand has two states. State H occurs with probability $\rho \in (0,1)$ and state L with probability $1 - \rho$. We define

$$A_H = \bar{A} + (1 - \rho)\Delta, \quad A_L = \bar{A} - \rho\Delta \quad (4)$$

where $\bar{A} > 0$, $\Delta > 0$, and $A_L > 0$. This construction yields

$$\mathbb{E}[A_z] = \bar{A}, \quad \text{Var}(A_z) = \rho(1 - \rho)\Delta^2 \quad (5)$$

The platform acts before A_z is realized, whereas the manufacturer and retailer set prices after observing the state. All firms are risk neutral in the main model. Risk aversion is discussed as an extension.

3.4 Profit and welfare functions

In state z , the profits of the platform, manufacturer, and retailer are

$$\pi_{P,z} = \tau p_{e,z} q_{e,z} \quad (6)$$

$$\pi_{M,z} = [(1 - \tau)p_{e,z} - c]q_{e,z} + (w_z - c)q_{o,z} \quad (7)$$

$$\pi_{R,z} = (p_{o,z} - w_z)q_{o,z} \quad (8)$$

where $c \geq 0$ is unit production cost. Expected platform profit deducts traffic-support cost once:

$$\Pi_P = \rho\pi_{P,H} + (1 - \rho)\pi_{P,L} - \frac{ks^2}{2} \quad (9)$$

Expected manufacturer and retailer profits are probability-weighted state profits. Consumer surplus follows from the same utility function:

$$CS_z = \frac{1}{2}(q_{e,z}^2 + q_{o,z}^2 + 2\mu q_{e,z}q_{o,z}) \quad (10)$$

and expected social welfare is

$$SW = \Pi_P + \Pi_M + \Pi_R + \rho CS_H + (1 - \rho)CS_L \quad (11)$$

Commission income is an internal transfer between platform and manufacturer and is not deducted a second time in (11).

3.5 Assumptions and solution concept

The platform cannot force participation. Let Π_M^O be the manufacturer's expected profit in the offline-only Model O. The platform problem is subject to

$$\Pi_M(\tau, s) \geq \Pi_M^O \quad (12)$$

We solve for a subgame-perfect equilibrium by backward induction. The compact policy domain $[0, \tau_{\max}] \times [0, s_{\max}]$, nonnegative demands, and the manufacturer participation condition define a closed feasible set. Continuity then guarantees existence whenever the feasible set is nonempty, concavity or KKT and boundary comparisons determine uniqueness and the global solution. Table 2 summarizes the notation.

Table 2. Notation and definitions

Symbol	Definition	Range/decision maker
M, R, P	Manufacturer, offline retailer, platform	Supply-chain members
e, o	Online agency and offline retail channels	Channel subscribers
$z \in \{H, L\}$	Demand state	Common information after realization
$\bar{A}, \Delta, \rho$	Mean market potential, state distance, high-state probability	$\bar{A} > 0, \Delta > 0, 0 < \rho < 1$
α	Baseline online preference	$0 < \alpha < 1$
μ	Channel substitutability	$0 \leq \mu < 1$
η	Online traffic conversion efficiency	$\eta > 0$
ϕ	Direct offline traffic effect	Positive, zero, or negative
τ	Proportional commission rate	Platform, $0 \leq \tau \leq \tau_{\max} < 1$

s	Traffic-support investment	Platform, $0 \leq s \leq s_{\max}$
k	Investment-cost coefficient	$k > 0$
c	Unit production cost	$c \geq 0$
$p_{e,z}, w_z$	Online price and wholesale price	Manufacturer
$p_{o,z}$	Offline price	Retailer
$q_{e,z}, q_{o,z}$	Channel demands	Nonnegative
$\bar{\tau}$	Regulatory commission cap	$0 \leq \bar{\tau} \leq \tau_{\max}$
λ	Manufacturer share of support cost	$0 \leq \lambda \leq 1$
$s_{\max}$	Finite traffic-support capacity	Exogenous, $s_{\max} > 0$

4. Benchmark Models

4.1 Offline-only outside option (Model O)

If the manufacturer rejects the agency contract, only the offline channel operates. To preserve the offline-oriented market segment from the utility model, define $B_z = (1 - \alpha)A_z$. Standard backward induction yields

$$w_z^O = \frac{B_z + c}{2}, \quad p_{o,z}^O = \frac{3B_z + c}{4}, \quad q_{o,z}^O = \frac{B_z - c}{4} \quad (13)$$

The solution requires $B_z > c$. The corresponding manufacturer and retailer profits are $(B_z - c)^2/8$ and $(B_z - c)^2/16$. Their expectations define the participation benchmark in (12).

4.2 Exogenous commission without traffic support (Model B)

Model B fixes $\tau = \tau_0$ and sets $s = 0$. The retailer's statewise best response is

$$p_{o,z}(w_z, p_{e,z}) = \frac{(1-\alpha)A_z - \mu\alpha A_z + \mu p_{e,z} + w_z}{2} \quad (14)$$

Substituting (14) into manufacturer profit yields a concave two-variable pricing problem under a regularity condition. Define

$$D(\tau, \mu) = 8(1 - \tau)(1 - \mu^2) - \mu^2 \tau^2 \quad (15)$$

When $D(\tau, \mu) > 0$, the downstream Hessian is negative definite, and the state equilibrium is unique. Prices and quantities are affine in A_z , s , and c , the coefficient expressions are reported in Appendix A.

4.3 Single-instrument decisions (Models C and S)

Model C allows the platform to choose commission but imposes $s = 0$. It isolates the extraction-versus-volume trade-off. Model S fixes commission at τ_0 and lets the platform choose support. For fixed τ , write downstream online price and demand as

$$p_{e,z}^* = P_A(\tau)A_z + P_s(\tau)s + P_c(\tau)c, \quad q_{e,z}^* = Q_A(\tau)A_z + Q_s(\tau)s + Q_c(\tau)c \quad (16)$$

Let $V = \text{Var}(A_z)$. Expected online revenue is

$$\begin{aligned} \mathbb{E}[p_e^* q_e^*] = & P_A Q_A (\bar{A}^2 + V) + (P_A Q_s + P_s Q_A) \bar{A} s \\ & + (P_A Q_c + P_c Q_A) \bar{A} c + P_s Q_s s^2 \\ & + (P_s Q_c + P_c Q_s) s c + P_c Q_c c^2 \end{aligned} \quad (17)$$

Thus, conditional on a fixed commission and an interior solution, the unconstrained optimal support is

$$s^u(\tau) = \frac{\tau[(P_A Q_s + P_s Q_A) \bar{A} + (P_s Q_c + P_c Q_s) c]}{k - 2\tau P_s Q_s} \quad (18)$$

The feasible solution projects the interior candidate in (18) onto the support interval $[0, s_{\max}]$ and then imposes positive-demand and manufacturer-participation constraints.

Proposition 1 (Downstream equilibrium and feasible platform problem). If $0 \leq \mu < 1$, $0 \leq \tau < 1$, and $D(\tau, \mu) > 0$, the retailer and manufacturer subgame has a unique interior equilibrium. The platform's candidate solution is obtained from its reduced-form profit subject to the commission and support bounds, demand nonnegativity, and (12). If any constraint binds, the equilibrium is a boundary solution rather than the unconstrained first-order solution. This proposition requires an interior stationary point to be compared with $s = 0$, commission boundaries, participation boundaries, and channel-exit points.

Proposition 2 (Traffic-support incentive at a fixed commission). Under Proposition 1 and $k - 2\tau P_s Q_s > 0$, positive traffic support is optimal if and only if the numerator of (18) is positive. Conditional on τ , additive demand variance V changes the level of expected platform profit but not the interior first-order condition for s . The last result is important. Demand variance appears in the first term of (17), which does not contain s . Uncertainty therefore affects support indirectly when commission is endogenous: it changes the return to commission and hence the selected τ , which then changes $s^u(\tau)$. The result identifies the channel through which uncertainty enters this timing structure.

4.4 Benchmark comparison and participation

The benchmark models separate the two instruments. Model C allows the platform to extract more commission but cannot expand the traffic base. Model S improves the traffic base while keeping the fee fixed. Their comparison with Model B reveals whether each instrument independently benefits or harms supply-chain members. The joint model can then be evaluated against both single-instrument cases rather than against an ambiguous status quo.

5. Joint Commission and Traffic-Support Investment

5.1 Equilibrium under joint decisions (Model J)

In Model J, the platform solves

$$\max_{0 \leq \tau \leq \tau_{\max}, 0 \leq s \leq s_{\max}} \tilde{\Pi}_p(\tau, s) \quad \text{s.t.} \quad \Pi_M(\tau, s) \geq \Pi_M^0, \quad q_{e,z}, q_{o,z} \geq 0 \quad (19)$$

The reduced-form objective substitutes all downstream equilibrium decisions. For an interior candidate, the first-order conditions are $\partial \tilde{\Pi}_p / \partial \tau = 0$ and $\partial \tilde{\Pi}_p / \partial s = 0$. The Hessian determines local concavity, while the constrained global solution is selected by boundary comparison. Figure 2 illustrates the baseline objective and feasible region.

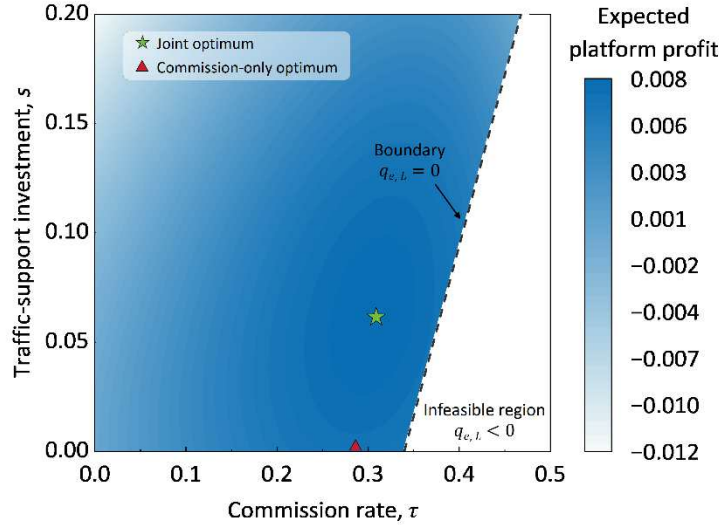


Figure 2. Reduced-form expected platform profit over commission and traffic support. The white region contains parameter combinations for which low-state online demand is negative, and the dashed boundary denotes $q_{e,L} = 0$. The star marks the constrained joint optimum, while the triangle marks the commission-only optimum at $s = 0$.

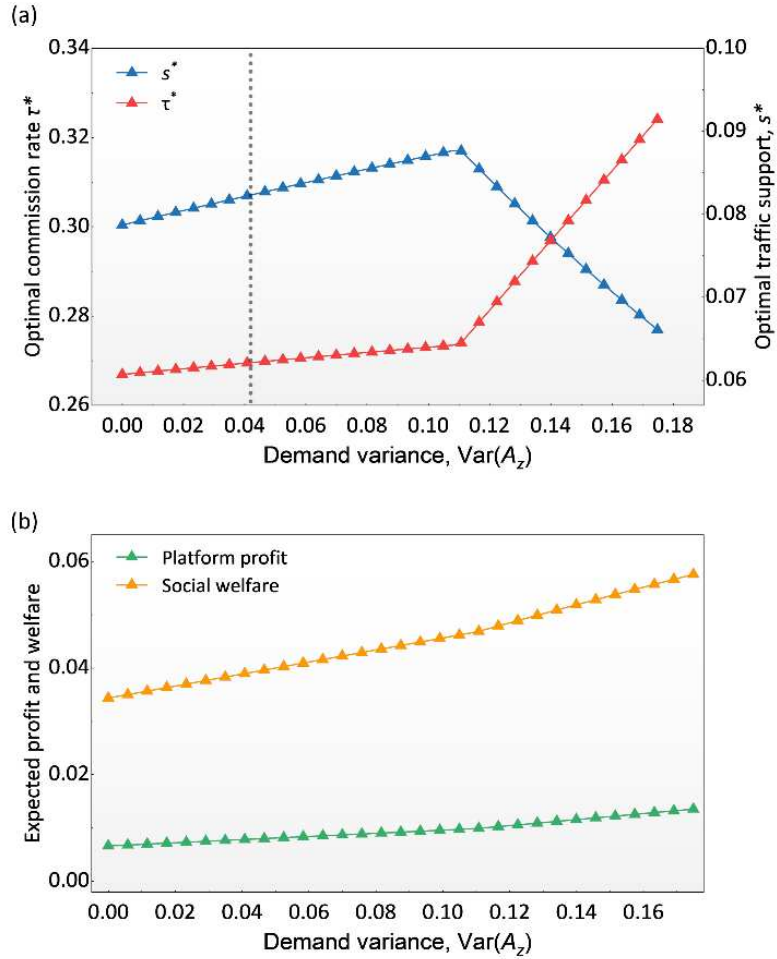


Figure 3. Effects of demand uncertainty on the platform's optimal policies and system outcomes. (a) Optimal commission and traffic-support decisions. (b) Expected platform profit and social welfare. The vertical dotted line denotes the baseline variance, $\text{Var}(A_z) = 0.0441$.

5.2 Commission-traffic support feedback: complementarity versus substitution

Define the local commission-traffic cross-incentive index

$$I_{\tau s} = \frac{\partial^2 \tilde{\Pi}_P(\tau, s)}{\partial \tau \partial s} \quad (20)$$

The index measures whether a marginal increase in commission raises or lowers the marginal return to support after downstream pricing responses are substituted. The following decomposition separates the platform's direct monetization gain from the endogenous pricing-volume response:

$$I_{\tau s} = D_{\tau s} - R_{\tau s} \quad (21)$$

The direct monetization term is positive because a higher commission lets the platform retain a larger share of support-generated online revenue. The response term captures the manufacturer's price adjustment, the resulting change in online volume, and any movement toward a binding participation or demand constraint. The two instruments are complementary only when the direct monetization effect dominates this induced response.

Proposition 3 (Commission-traffic feedback). At an interior feasible equilibrium, commission and traffic support are locally complementary when the direct monetization effect exceeds the endogenous pricing-volume response, locally substitutable when the reverse inequality holds, and locally independent at equality. The sign cannot be inferred from the positive commission share alone, it must be evaluated after manufacturer and retailer pricing responses. The baseline domain in Figure 4 remains complementary, but the contour variation shows how higher support intensity and active constraints compress the complementarity margin.

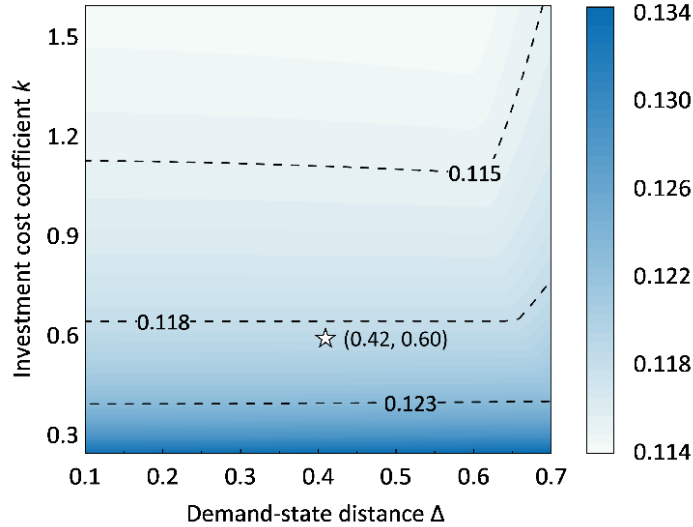


Figure 4. Equilibrium cross-incentive index across demand-state distance and the traffic-support cost coefficient. The index remains positive in the displayed baseline domain, labeled contours show changes in complementarity strength, and the star denotes the baseline parameter pair (0.42, 0.60).

5.3 Commission-mediated transmission of demand uncertainty

At a fixed commission, Proposition 2 implies that additive demand variance changes expected platform revenue but does not enter the interior support first-order condition directly. Once commission is endogenous, however, variance changes the profitability of the commission profile and therefore the selected commission. The support response can be decomposed as

$$\frac{ds^*}{dV} = \frac{\partial s^*}{\partial \tau} \frac{d\tau^*}{dV} \quad (22)$$

on any unchanged interior branch. The first component is zero under the additive-shock specification at a fixed commission, so the total effect is transmitted through the commission response. This commission-

mediated channel is the reason uncertainty can matter for support even when the direct fixed-commission effect vanishes.

Proposition 4 (Commission-mediated uncertainty transmission). Within an interior region, demand uncertainty changes support through the product of the support response to commission and the commission response to variance. If these two responses have the same sign, uncertainty increases support, if they have opposite signs, uncertainty reduces support. At participation, commission, support-capacity, or demand boundaries, a branch change can generate a nonmonotonic response.

The baseline experiment in Figure 3 confirms this pattern. The optimal commission increases gradually with demand variance, peaks at approximately $\text{Var}(A_z) = 0.108$ (equivalently, $\Delta \approx 0.66$), and then declines. Optimal support rises only slightly at first but increases more sharply after the solution approaches a different constrained branch. This nonmonotonicity is an equilibrium response rather than an assumed functional form.

5.4 Channel spillover, conflict, and profit allocation

Differentiating the equilibrium demands with respect to support yields two analytical thresholds. Offline demand increases with support if

$$\phi > \phi_o(\mu, \tau) \equiv \frac{\eta\mu(2-\tau)}{2} \quad (23)$$

Online demand increases provided

$$\phi < \phi_e(\mu, \tau) \equiv \frac{2\eta(1-\tau)(2-\mu^2)}{\mu(2-\tau)} \quad (24)$$

Under the regular interior region, $\phi_o < \phi_e$. Thus three economically distinct cases arise.

Proposition 5 (Market-expansion and migration thresholds). If $\phi < \phi_o$, traffic support expands online demand but contracts offline demand. If $\phi_o \leq \phi \leq \phi_e$, both channel demands increase. If $\phi > \phi_e$, the direct offline spillover is so strong that offline demand increases while equilibrium online demand decreases. Figure 5 maps these regions. The result clarifies why a positive traffic effect should not automatically be labeled a network effect. The direct spillover ϕ and price-driven substitution μ have separate roles. Figure 6 further shows that stronger offline spillover shifts value toward the manufacturer and retailer, while the platform reduces support because more of its investment benefit leaks outside the commission base.

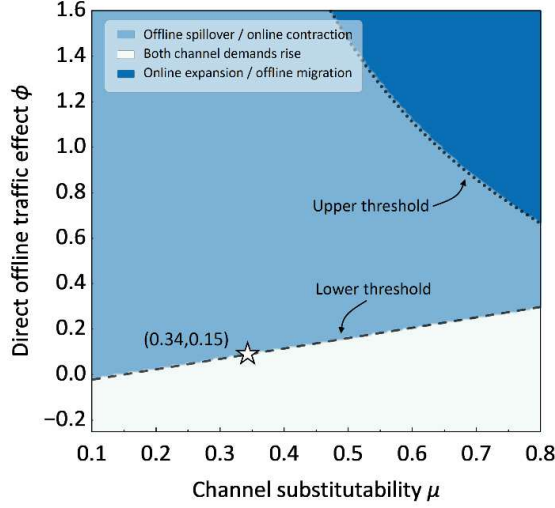


Figure 5. Analytical marginal market-expansion and channel-migration regions. The star denotes the baseline. The dashed lower threshold satisfies $\frac{dq_o}{ds} = 0$, and the dotted upper threshold satisfies $\frac{dq_e}{ds} = 0$.

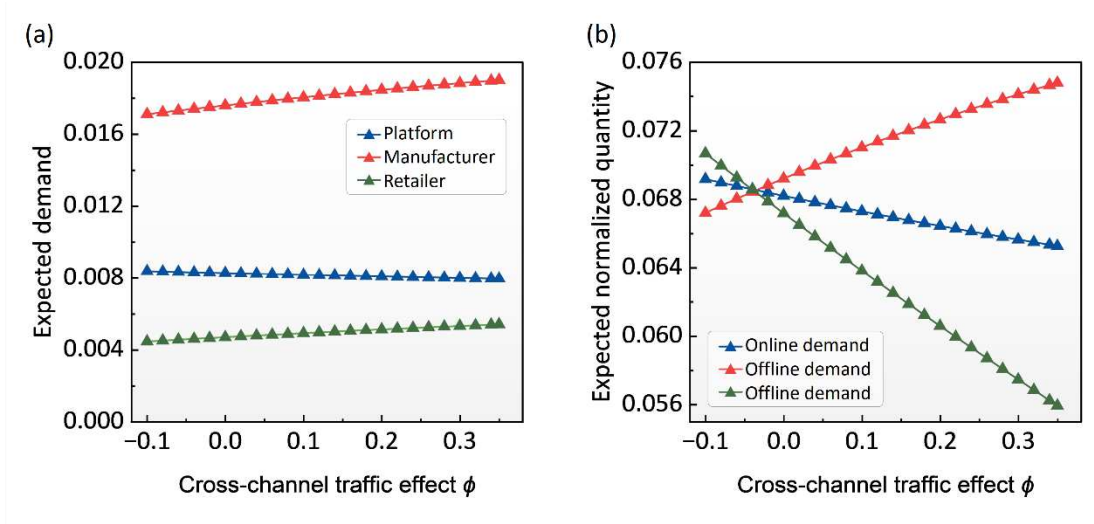


Figure 6. Effects of the cross-channel traffic parameter on stakeholder profits, expected channel demands, and optimal support. The vertical dotted line denotes the baseline value $\phi = 0.15$.

6. Consumer Welfare and Regulatory Analysis

6.1 Consumer surplus and social welfare

Platform profit is not a welfare measure. A higher commission may increase platform revenue while raising the manufacturer's effective online marginal cost and reducing consumer surplus. Conversely, a lower commission may reduce the platform's support. We therefore evaluate consumer surplus from (10) and social welfare from (11).

The centralized-profit benchmark integrates the three firms and selects prices and support to maximize total operating profit, commission disappears because it is an internal transfer. This benchmark measures decentralization loss from the firms' perspective, but it is not a social first best because consumer surplus is not internalized. We therefore also report a social-planner first best that maximizes total surplus subject to the same support-capacity constraint. Both are conceptually different from a policy problem in which a regulator constrains commission while firms remain decentralized.

6.2 Welfare decomposition and platform-policy divergence

Suppose a regulator selects a commission target while the platform reoptimizes support and downstream firms continue to price strategically. Let $s_P(\tau)$ denote the platform's support response. The welfare-oriented commission solves the policy problem below.

$$\tau^{SW} \in \arg \max_{0 \leq \tau \leq \tau_{\max}} SW[\tau, s(\tau)] \quad (25)$$

Along the platform's support response, the marginal welfare effect decomposes into a direct commission effect and an endogenous support-feedback effect:

$$\frac{dSW(\tau, s_P(\tau))}{d\tau} = \frac{\partial SW}{\partial \tau} + \frac{\partial SW}{\partial s} \frac{ds_P}{d\tau} \quad (26)$$

The first term captures the direct pricing, margin, and consumer-surplus effect of changing the commission. The second captures the welfare consequence of the induced support adjustment. A fee reduction is welfare improving only when the direct gain exceeds the welfare loss associated with the endogenous support response.

Proposition 6 (Platform-policy divergence). The platform-optimal commission need not equal the welfare-oriented commission. A lower policy commission raises welfare if and only if the direct pricing-surplus gain dominates the endogenous support-feedback loss along $s_P(\tau)$. Consequently, commission regulation evaluated while holding support fixed can have the wrong sign and overstate the benefit of a restrictive cap.

Figure 7 displays the baseline divergence. The platform-optimal commission is 0.3074, whereas the welfare-oriented commission is 0.1035. The lower policy commission raises consumer surplus but reduces optimal support from 0.0622 to 0.0203. Despite the investment reduction, social welfare increases by approximately 7.1% relative to Model J because the pricing and demand effects dominate.

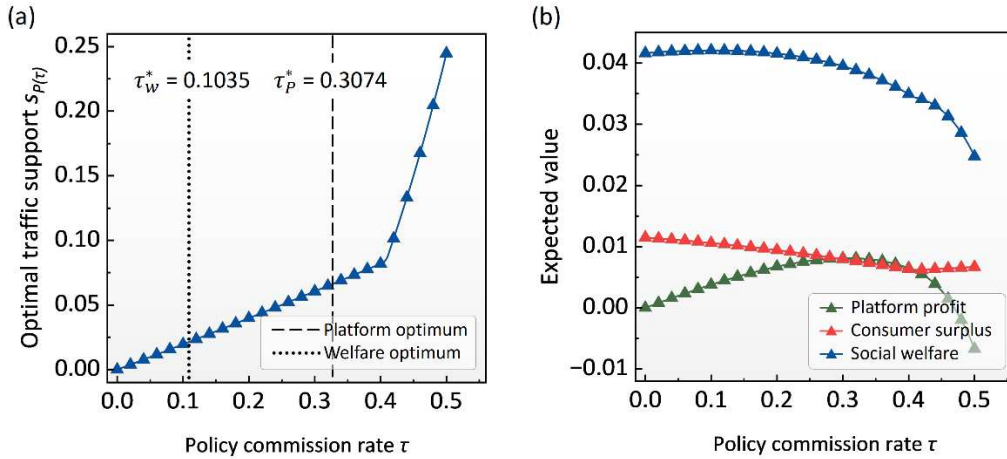


Figure 7. Endogenous traffic-support response and platform-welfare divergence across policy commission rates. The dotted and dashed vertical lines denote the welfare-oriented commission (0.1035) and the unregulated platform optimum (0.3074), respectively.

6.3 Commission-cap regulation

Let $\bar{\tau}$ be a regulatory cap. The platform chooses $\tau \leq \bar{\tau}$ and reoptimizes support. Three regions arise. If $\bar{\tau} \geq \tau^{J*}$, the cap is nonbinding. If $\tau^{SW} < \bar{\tau} < \tau^{J*}$, tightening the cap can improve welfare. If the cap is pushed below the welfare optimum, further tightening weakens support and yields diminishing or negative welfare gains.

In the baseline, social welfare peaks near a commission rate of 0.1035. A cap of 0.04 remains welfare-improving relative to the unregulated case, but optimal support falls to approximately 0.0078, illustrating the investment cost of severe restrictions. Commission regulation should therefore account for the platform's endogenous demand-generation response rather than treating lower commission as uniformly beneficial.

6.4 Traffic-support cost sharing and Pareto improvement

Consider a cooperative mechanism under which the manufacturer bears fraction λ of the support cost and the platform bears $1 - \lambda$. The platform objective becomes

$$\Pi_P^\lambda = \mathbb{E}[\tau p_e q_e] - (1 - \lambda) \frac{ks^2}{2} \quad (27)$$

and manufacturer profit deducts $\lambda ks^2/2$. Social welfare still deducts the full real cost only once.

Cost sharing reduces the platform's marginal investment cost and increases support. However, excessive manufacturer sharing can bind its participation constraint. We define a multi-stakeholder improvement as a policy that weakly raises platform, manufacturer, retailer, and consumer outcomes relative to Model J, with at least one strict gain.

Proposition 7 (Cost sharing and policy regions). If the marginal increase in the manufacturer's operating profit from additional support exceeds its allocated marginal cost, a positive cost-sharing interval exists in which support and all stakeholder outcomes weakly increase. Once the manufacturer's participation constraint binds, further sharing cannot be a manufacturer-inclusive Pareto improvement.

In the baseline numerical model, weak multi-stakeholder improvement holds from the Model J benchmark at $\lambda = 0$ through approximately $\lambda = 0.2677$, strict improvement holds for $0 < \lambda < 0.2677$. Beyond that range, the manufacturer is the first stakeholder to fall below its Model J payoff, even though the platform continues to increase support. Figure 8 summarizes the cost-sharing and commission-cap regions.

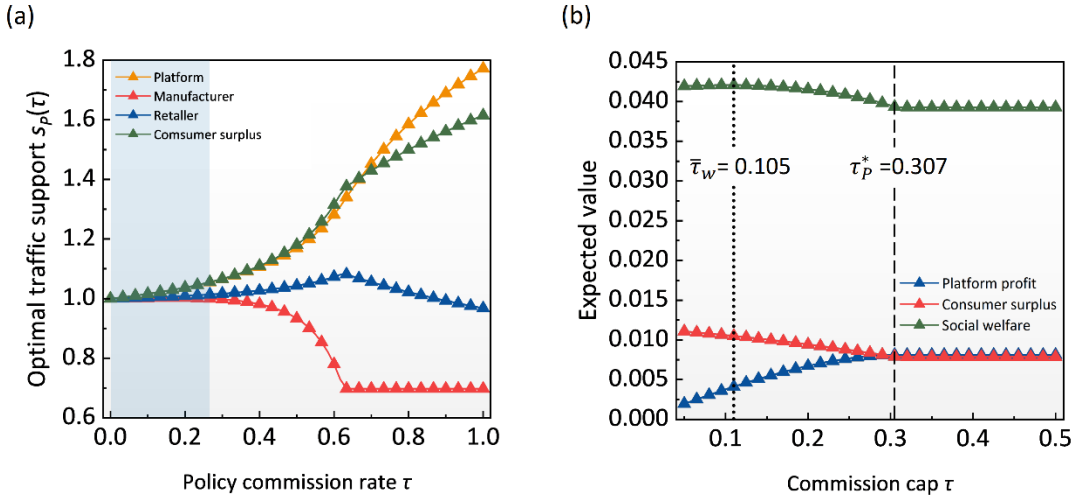


Figure 8. Policy coordination through cost sharing and commission caps. (a) Stakeholder outcomes relative to Model J, the shaded interval denotes weak multi-stakeholder improvement. (b) Platform profit, consumer surplus, and social welfare under alternative commission caps when support is reoptimized.

7. Numerical Analysis and Scenario-Based Parameterization

7.1 External data relevance and identification limits

The numerical analysis quantifies the theoretical mechanisms and verifies the constrained solution, it does not claim causal empirical validation. Public e-commerce datasets can motivate plausible ranges for demand variation and traffic-conversion efficiency. For example, the UCI Online Shoppers Purchasing Intention dataset contains session-level browsing attributes and purchase outcomes, the UCI Online Retail II dataset contains transaction records, and the Retailrocket clickstream data characterize view-to-cart-to-purchase funnels. None jointly observes dynamic platform commissions, traffic allocation, and matched online-offline sales, so the full structural model is not identified from these sources.

We therefore normalize expected market potential to one. Demand-state distance and online preference are selected as medium-range scenarios rather than statistically estimated values. The traffic coefficient is scaled to $\eta = 0.50$. Channel substitution, direct offline spillover, and investment cost are varied broadly

because they are not directly identified by a single public dataset. No confidence interval is assigned to an unidentifiable parameter.

7.2 Parameterization and baseline results

Table 3. Baseline parameterization

Parameter	Baseline	Interpretation	Basis
$\bar{A}$	1	Normalized expected market potential	Normalization
ρ	0.5	Probability of high-demand state	Symmetric main model
Δ	0.42	Distance between demand states	Medium uncertainty scenario
α	0.48	Baseline online preference	Scenario range 0.42-0.60
μ	0.34	Channel substitutability	Moderate substitution
η	0.5	Traffic conversion efficiency	Normalized moderate efficiency
ϕ	0.15	Direct offline spillover	Slightly above expansion threshold
c	0.22	Unit production cost	Normalized margin scenario
k	0.6	Traffic-investment cost coefficient	Moderate convex cost
τ_0	0.15	Exogenous benchmark commission	Illustrative benchmark
τ_{max}	0.5	Technical commission upper bound	Compact feasible set
s_{max}	0.25	Finite traffic-support capacity	Compact support domain

The baseline satisfies positive demand in both states, the manufacturer participation constraint, and the downstream concavity condition. Table 4 reports model-level outcomes, all monetary and quantity measures are normalized. The baseline parameter values, their interpretations, and the basis for their selection are summarized in Table 3.

Table 4. Baseline equilibrium and welfare outcomes

Model	Commission rate	Traffic support	Platform profit	Manufacturer profit	Retailer profit	Aggregate firm profit	Consumer surplus	Social welfare
O	-	0	0	0.0127	0.0064	0.0191	0.0032	0.0223
B	0.1500	0	0.0051	0.0209	0.0042	0.0302	0.0092	0.0395
C	0.2839	0	0.0071	0.0169	0.0049	0.0289	0.0070	0.0358
S	0.1500	0.0296	0.0054	0.0223	0.0042	0.0319	0.0101	0.0420
J	0.3074	0.0622	0.0081	0.0183	0.0050	0.0314	0.0079	0.0393
Centralized-profit benchmark	-	0.1319	n.a.	n.a.	n.a.	0.0378	0.0215	0.0593
Welfare-policy optimum	0.1034	0.0203	0.0039	0.0236	0.0040	0.0315	0.0106	0.0421
Social planner*	-	0.2500	n.a.	n.a.	n.a.	n.a.	n.a.	0.0877

Note: For decentralized models, aggregate firm profit equals the sum of platform, manufacturer, and retailer profits. The centralized-profit benchmark reports aggregate firm profit only. The social planner maximizes total surplus directly, so stakeholder profits and consumer surplus are not separately identified.

Model C chooses commission 0.284 without support. Model S, with commission fixed at 0.15, chooses support 0.030. The joint model chooses commission 0.307 and support 0.062. Relative to Model C, joint optimization increases platform profit by 14.1%, manufacturer profit by 8.2%, retailer profit by 3.2%,

consumer surplus by 13.0%, and social welfare by 9.6%. This comparison demonstrates complementarity in the baseline: adding support does not merely transfer value to the platform, it expands the feasible transaction base enough to benefit all parties relative to the commission-only benchmark.

Relative to the lower-commission Model B, however, Model J raises platform profit by 58.0% while reducing manufacturer profit by 12.7% and consumer surplus by 14.8%. Social welfare is nearly unchanged. The choice of benchmark therefore matters: a joint policy can dominate a single-instrument optimum but still represent a more extractive outcome than a low-commission exogenous regime.

The state-contingent equilibrium in Table 5 shows that prices and quantities respond strongly to demand realization. The low state remains active in both channels, which validates the interior analysis for the baseline.

Table 5. State-contingent decisions in Model J

State	A	p_e	p_o	w	q_e	q_o	π_P	π_M	π_R	CS
H	1.21	0.4719	0.5073	0.4236	0.1078	0.0946	0.0156	0.0308	0.0079	0.0138
L	0.79	0.3677	0.3622	0.3187	0.0259	0.0491	0.0029	0.0057	0.0021	0.002

7.3 Phase diagrams and policy regions

Figure 2 verifies the joint optimum against the feasible profit surface. Figure 3 shows that demand uncertainty produces a nonlinear policy response. Figure 5 identifies market-expansion regions analytically. Figures 7 and 8 show that welfare and Pareto regions depend on policy feedback through support.

The numerical values also illustrate two different efficiency gaps. The centralized-profit benchmark selects support 0.1319 and delivers social welfare 0.0593, so Model J is approximately 33.8% below this benchmark. The capacity-constrained social planner selects $s = s_{\max} = 0.2500$ and delivers welfare of approximately 0.0877, Model J is therefore about 55.2% below the social-planner benchmark. The first gap reflects vertical pricing and incomplete capture of support benefits, while the second additionally reflects the firms' failure to internalize consumer surplus.

7.4 Global verification and Monte Carlo sensitivity

Every plotted optimum was checked against commission, support-capacity, participation, and positive-demand boundaries. For the baseline, constrained multistart optimization and a commission-profile search agree. We then use a 500-draw Latin-hypercube design over $\Delta \in [0.10, 0.75]$, $\alpha \in [0.35, 0.65]$, $\mu \in [0.05, 0.65]$, $\eta \in [0.25, 0.80]$, $\varphi \in [-0.10, 0.45]$, $c \in [0.05, 0.30]$, and $k \in [0.30, 1.50]$, retaining only feasible draws. For each draw, we solve Models C and J, evaluate a 20% tighter commission cap, record the cross-incentive sign, and identify active policy boundaries.

Across the 500 feasible draws, Model J yields at least as much platform profit as Model C in 95.8% of cases, and a 20% tighter commission cap improves welfare in 84.6%. The cross-incentive is positive throughout this central parameter box, the substitutable region in Figure 4(b) requires more extreme spillover/substitution combinations. The commission is interior in 71.2% of draws, while support is interior in 95.2%, confirming that boundary checks are economically relevant. These shares are numerical sensitivity evidence, not universal theorems. Figure 9 reports the numerical verification and directional checks.

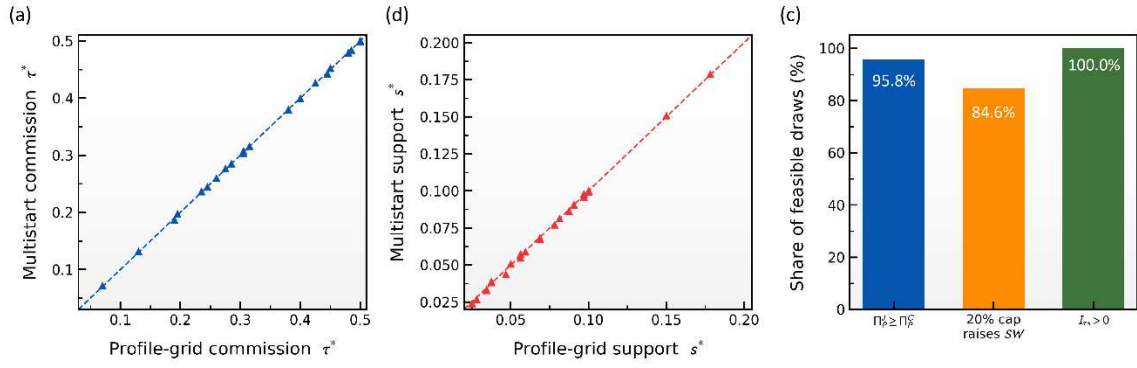


Figure 9. Numerical verification and robustness direction checks. Panels (a) and (b) compare multistart and profile-grid solutions for 35 representative feasible draws, dashed lines are 45-degree benchmarks. Panel (c) reports the shares of 500 feasible Latin-hypercube draws satisfying each directional comparison.

8. Extensions and Robustness

8.1 Risk-averse decision makers

The main model assumes risk neutrality. If the platform evaluates a mean-variance objective $\Pi_p - \gamma_p \text{Var}(\pi_{p,z})$ or a lower-tail CVaR criterion, high-state revenue becomes less attractive relative to the sunk support cost. Risk aversion therefore tends to reduce the variance-driven incentive to raise commission and can reduce support, although the sign remains conditional on the commission-support cross effect. The downstream equilibrium remains unchanged if only the platform is risk averse, the platform problem changes through an additional state-dispersion term.

8.2 Alternative information and decision timing

If downstream prices must be committed before demand is observed, state-contingent adaptation disappears. In that case, additive demand uncertainty may again drop out of a risk-neutral expected-profit first-order condition unless inventory, capacity, or nonlinear demand is introduced. This observation reinforces the importance of matching the uncertainty specification to an economically meaningful timing assumption. A separate extension could allow the platform to observe a private demand signal, creating information rents and information-sharing decisions similar to Avinadav et al. (2026). Such an extension should not be conflated with the common-information main model.

8.3 Alternative demand and investment-cost specifications

The quadratic utility produces linear demands and transparent thresholds. The qualitative mechanisms can be tested under logit demand, multiplicative market size, or convex investment costs ks^r/r with $r > 1$. The exact thresholds would change, but three requirements remain: the support decision must affect a transaction base, commission must alter the platform's return from that base, and downstream prices must respond to both. The market-expansion result is expected to persist whenever the direct offline spillover can offset price-induced channel migration.

9. Conclusions

This study develops a joint model of platform value extraction and demand generation. The platform selects commission and traffic support before demand is realized, the manufacturer decides whether to participate, and downstream prices adjust after the state becomes common information. The utility-based demand system keeps channel quantities and consumer surplus internally consistent, while the constrained Stackelberg solution accounts for participation, demand, and policy boundaries. The commission-traffic cross-incentive is the central mechanism. A higher commission improves the platform's return from support-generated transactions, but the manufacturer's price response reduces online volume and weakens that return. The sign

of the cross-incentive depends on the balance between these effects. The baseline parameter region is complementary, although the strength of complementarity varies with demand and investment conditions. Demand uncertainty affects support through the commission decision in the main timing structure. At a fixed commission, additive variance does not directly change the interior support condition. Once commission is endogenous, changes in uncertainty alter the commission profile and are transmitted to support. This indirect channel explains the nonlinear response observed near feasibility boundaries.

Traffic support does not always expand the total market. The two spillover thresholds distinguish online expansion with offline migration, simultaneous expansion of both channels, and offline expansion accompanied by online contraction. The thresholds separate the direct offline spillover from price-mediated channel substitution and provide a clearer basis for interpreting platform traffic policies. The policy results follow from the same feedback. A commission cap affects welfare through prices and consumer surplus, and through the platform's support response. The welfare-oriented commission is below the platform optimum in the baseline, but an excessively tight cap reduces support and can reverse part of the welfare gain. Moderate manufacturer cost sharing increases support and can improve platform, manufacturer, retailer, and consumer outcomes over a limited interval. The analysis is mechanism based and uses normalized scenario ranges rather than structural estimation. Future research can estimate commission and traffic responses with matched platform-merchant data, allow state-adaptive support, introduce competing sellers and inventory decisions, and study discriminatory allocation of platform visibility.

Appendix A. Downstream Equilibrium Coefficients

Let $D = 8(1 - \tau)(1 - \mu^2) - \mu^2\tau^2$. The equilibrium online price and demand can be written as (16), where

$$P_A = \frac{3\alpha\mu^2\tau - 4\alpha\mu^2 - \alpha\mu\tau - 4\alpha\tau + 4\alpha + \mu\tau}{D} \quad (28)$$

$$P_S = \frac{3\eta\mu^2\tau - 4\eta\mu^2 - 4\eta\tau + 4\eta + \mu\phi\tau}{D} \quad (29)$$

$$P_C = \frac{(\mu - 1)(\mu\tau - 4\mu - 4)}{D} \quad (30)$$

$$Q_A = \frac{2\alpha\mu^2\tau - 2\alpha\mu^2 - \alpha\mu\tau + 2\alpha\mu - 4\alpha\tau + 4\alpha + \mu\tau - 2\mu}{D} \quad (31)$$

$$Q_S = \frac{2\eta\mu^2\tau - 2\eta\mu^2 - 4\eta\tau + 4\eta + \mu\phi\tau - 2\mu\phi}{D} \quad (32)$$

$$Q_C = \frac{2\mu^2 - \mu\tau + 2\mu - 4}{D} \quad (33)$$

The remaining equilibrium variables are obtained by substituting $p_{e,z}^*$ and w_z^* into the retailer response (14). The complete symbolic expressions are generated by the accompanying reproducibility script rather than manually retyped into the main text.

Appendix B. Proof Sketches

Proof of Proposition 1. The retailer objective is strictly concave in the offline price. Substituting its best response into manufacturer profit yields a two-dimensional quadratic objective, the downstream regularity condition makes the manufacturer Hessian negative definite and establishes the unique statewise interior equilibrium. The platform objective is continuous, and its feasible set is a closed subset of the compact rectangle $[0, \tau_{\max}] \times [0, s_{\max}]$ after the demand and participation constraints are imposed. A platform optimum therefore exists whenever the feasible set is nonempty. Strict concavity establishes uniqueness only within the stated parameter region, otherwise all KKT and boundary candidates must be compared.

Proof of Proposition 2. Substitute the affine expressions in (16) into expected online revenue and use $\mathbb{E}[A_z] = \bar{A}$ and $\mathbb{E}[A_z^2] = \bar{A}^2 + V$. Differentiation with respect to s yields a linear first-order condition whose solution is (18). The term containing V is independent of s , establishing the fixed-commission result.

Proof of Proposition 3. After substituting the downstream equilibrium, expected online revenue is a quadratic function of traffic support. Differentiating the reduced platform objective first with respect to support and then with respect to commission gives the cross-incentive index $I_{\tau s}$. A positive value means that a higher commission raises the marginal return to support, whereas a negative value means that the induced downstream price and volume responses dominate. The sign comparison is valid on an interior branch with a nonzero regularity denominator.

Proof of Proposition 4. Collect the platform's two interior first-order conditions in a system indexed by commission, support, and demand variance. The implicit-function theorem maps a change in variance into changes in the two optimal policy instruments through the inverse platform Hessian. The scalar transmission relationship stated in Proposition 4 follows from this system and remains valid only while the same interior branch and active-constraint set are preserved.

Proof of Proposition 5. Differentiate the equilibrium channel demands with respect to s . After collecting terms and using $D > 0$, the sign of $\partial q_o^* / \partial s$ is the sign of $2\phi - \eta\mu(2 - \tau)$, which gives (23). The sign of $\partial q_e^* / \partial s$ gives (24). Combining the two inequalities yields the three regions.

Proof of Proposition 6. Along the platform's support response $s_P(\tau)$, social welfare is a composite function of the policy commission. Its derivative equals the direct welfare effect of the commission plus the indirect effect operating through the platform's support response. A marginal tightening improves welfare when this total derivative is negative at the unregulated solution. If a support, participation, or demand constraint changes status, the derivative must be evaluated piecewise.

Proof of Proposition 7. Cost sharing reduces the platform's effective support-cost share to $1 - \lambda$ and charges the manufacturer $\lambda ks/2$. At $\lambda = 0$, if the manufacturer's marginal operating-profit gain generated by the induced increase in support exceeds its allocated marginal cost, continuity implies a positive interval in which all four stakeholder outcomes are weakly higher than under Model J. The interval ends when a stakeholder payoff-numerically, the manufacturer's crosses its Model J level or when a feasibility constraint becomes active.

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