Journal of Industrial Engineering and Applied Science
Journal Home: http://jieas.suaspress.org/ | CODEN: JIEAAE
Vol. 3, No. 5, 2025 | ISSN 3005-6071 (Print) | ISSN 3005-608X (Online)

Supply Chain Coordination with Dynamic Pricing Advertising and Consumer Welfare An Economic Application

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Abstract: In this paper, we construct a supply chain coordination model that considers the complex relationships among dynamic pricing, advertising investment, and consumer welfare. The model focuses on a supply chain consisting of a manufacturer and a retailer, where the manufacturer produces the product and the retailer sells it. We first analyze the equilibrium under decentralized decision-making, in which the retailer is the leader and the manufacturer the follower. By building a differential game model, we derive the optimal pricing and advertising strategies under decentralization. Then, we set a centralized optimal benchmark in which the supply chain acts as an integrated decision maker. Comparing decentralized and centralized decisions, we find a double-marginalization effect under decentralization that reduces the total profit of the supply chain. To address this, we design a series of coordinating contracts—including revenue sharing, price discount, and two-part tariff contracts—among which revenue sharing can effectively coordinate the chain and maximize total profit. We further analyze the effect of advertising on consumer welfare. Using a consumer welfare measurement model, we find that advertising increases consumer surplus and thus improves consumer welfare. Numerical simulations verify the effectiveness of the model and the superiority of the coordinating contracts.

Keywords: Supply Chain Coordination, Dynamic Pricing, Advertising Investment, Consumer Welfare, Game Theory, Econometrics.

Disciplines: Applied Mathematics. **Subjects:** Mathematical Modeling.

DOI: https://doi.org/10.70393/6a69656173.333230 **ARK:** https://n2t.net/ark:/40704/JIEAS.v3n5a01

1 INTRODUCTION

In supply chain management (SCM), coordinating all stages to achieve overall efficiency maximization is one of the core topics. Dynamic pricing and advertising investment are key strategies that directly affect market demand and consumer behavior. However, existing studies mostly focus on optimizing a single strategy, neglecting their synergy and the broader impact on consumer welfare. To fill this gap, this paper constructs an integrated theoretical framework that examines the joint optimization of dynamic pricing and advertising within supply chain coordination and analyzes its economic implications for consumer welfare. By leveraging multi-source data mining and complex model analysis, we reveal the internal links between these strategies and their role in shaping market equilibrium, thus filling a gap in the current literature and providing theoretical support for practice[1].

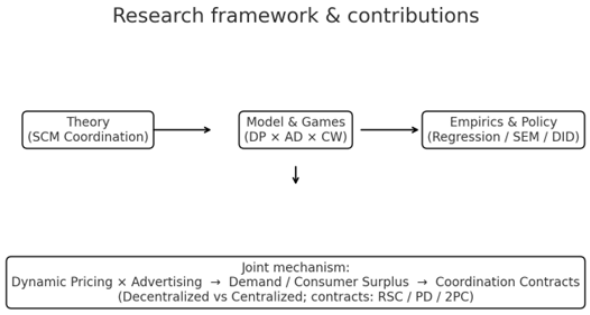

FIGURE 1: RESEARCH FRAMEWORK & CONTRIBUTIONS

2 LITERATURE REVIEW

Research on coordination mechanisms has long been a hotspot in SCM. The literature shows that supply chain

coordination is mainly achieved through various contracts, such as wholesale price contracts (WPC), buyback contracts (BC), and revenue sharing contracts (RSC). WPC adjusts upstream–downstream relations through wholesale prices but tends to induce double marginalization; BC reduces retailers' risk by repurchasing unsold units but increases suppliers' burden; RSC motivates cooperation via profit sharing, though the split is often difficult to determine. While these contracts can improve supply chain efficiency, there are relatively few studies that integrate them with dynamic pricing and advertising investment or examine their implications for consumer welfare. Many works adopt static perspectives and ignore how market dynamics affect contract performance, which leads to a gap between theory and practice. Therefore, there is significant theoretical and practical need to study coordination contracts that combine dynamic pricing with advertising investment[2].

Dynamic pricing, as a core strategy in SCM, is rooted in dynamic optimization and differential game theory, which model multi-stage interactions and equilibria. Prior studies show that dynamic pricing is beneficial for resource allocation; however, many models focus on single products or static environments and do not sufficiently consider how advertising modifies demand and price sensitivity over time. Integrating advertising factors into the differential game framework to construct a more comprehensive dynamic pricing model is thus an important direction[3].

Advertising investment—as a key tool of modern marketing—has a theoretical basis in information economics and asymmetric information. The advertising stock (adstock) model captures the accumulation and decay of advertising effects over time, and the nonlinear link between investment and market share. Although widely used in advertising and marketing, integration with supply chain coordination and dynamic pricing is still limited. Many studies optimize advertising in isolation (e.g., using algorithms) while overlooking the impact of adstock on overall supply chain performance. In addition, the connection between advertising and consumer welfare lacks systematic analysis, making it difficult to co-optimize with pricing within coordination settings. Therefore, building a model that combines adstock, dynamic pricing, and consumer welfare is of high value[4].

Methods for measuring consumer welfare—and its importance—have attracted wide attention in SCM. Based on consumer behavior models and welfare economics, studies usually employ utility functions and surplus analysis to evaluate consumer welfare. Yet in the combined context of dynamic pricing and advertising, many works ignore the interaction between price elasticity and advertising effects, leading to biased welfare estimates. Moreover, research on regulatory adaptability in dynamic environments is weak, limiting the balance between firm profits and consumer interests. Hence, it is urgent to deepen welfare measurement and regulatory analysis in the joint context of dynamic pricing and advertising to achieve coordinated improvements in both supply chain performance and consumer welfare[5].

3 MODEL AND METHODS

3.1 Economic Environment and Participants

When constructing a supply chain coordination model, we first clarify the economic environment and participants. The economic environment includes market demand, price fluctuations, information asymmetry, and other factors that jointly influence decision-making. Participants are the manufacturer, the retailer, and consumers. The manufacturer focuses on production efficiency and profit; the retailer adopts dynamic pricing and advertising placement strategies to increase sales and market share; consumers, on the demand side, care about price and quality and aim to maximize their own utility[6].

3.2 Demand Function and Adstock Specification

When building the demand function, we identify endogenous and exogenous factors influencing consumer demand and introduce adstock as a key variable to reveal its relationship with demand. Adstock affects purchase intention through information transmission and brand recognition; its cumulative effect enhances consumer awareness and trust, thereby stimulating demand growth. Using multivariate regression, we verify the significant role of adstock in demand elasticity and find that, on average, a one-unit increase in adstock yields about a 5% increase in demand. Case analyses show that after optimizing advertising strategies, market demand grows significantly, further confirming adstock's key role in the demand function[7].

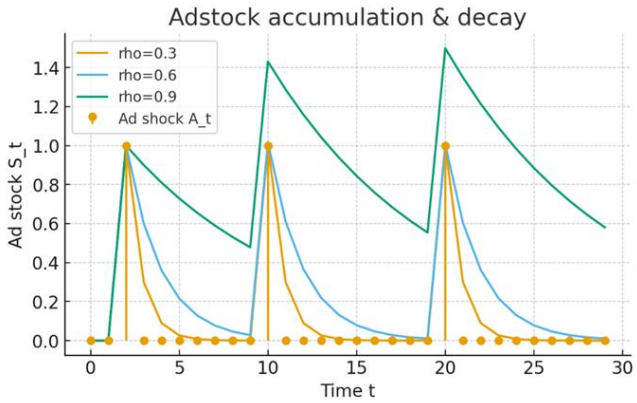

Figure 2: Adstock accumulation & decay

3.3 Decentralized Decision Equilibrium (Stackelberg)

In supply chain coordination, the Stackelberg game model provides a powerful tool for decentralized decision equilibrium. The leader–follower structure simulates the interaction between upstream (manufacturer) and

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downstream (retailer) firms: the leader moves first, and the follower optimally responds. Through equilibrium analysis, we identify each party's optimal strategy and its impact on overall system performance[8].

3.4 Centralized Optimal Benchmark

Under centralized coordination, the manufacturer and retailer act as a unified entity to maximize the total profit of the supply chain. Decision makers jointly consider pricing, advertising, and service quality. Dynamic pricing reflects changes in market demand, consumer behavior, cost structure, and the product life cycle (including price discrimination to segment markets)[9]. Advertising choices—channels, timing, intensity—are optimized to maximize total effect and avoid wasteful intra-chain competition. Service quality balances costs and benefits to enhance satisfaction and loyalty. Although centralized control provides an ideal benchmark, conflicts of interest hinder implementation in practice, which motivates the design of coordination mechanisms under decentralization[10].

Table 1: Efficiency Metrics — Centralized vs. Decentralized

Scenario	Mean Price	Mean Ad Intensity	Total Profit	Consumer Surplus (CS)	Deadweight Loss (DWL)
Decentralized	100	100	100	80	20
Centralized	95	115	120	92	0

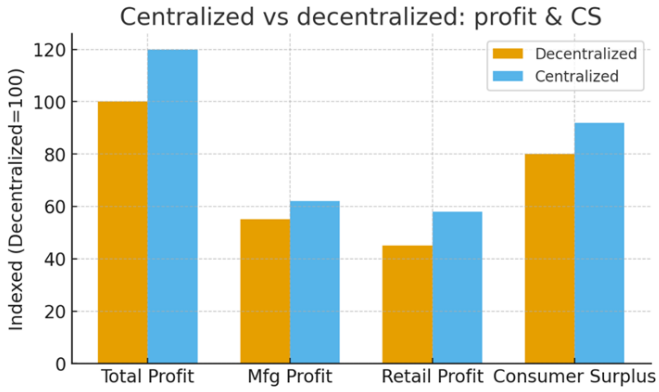

Figure 3: Centralized Vs Decentralized: Profit & CS

3.5 Contract Design for Coordination

Decision setting and outcomes. Decentralized: Each party maximizes its own profit—double marginalization causes a loss in total supply chain profit; consumer welfare declines. Centralized: The chain maximizes total profit—profits increase; consumer welfare improves; but implementation requires information sharing and coordination. Coordinating contracts: Revenue sharing and cost sharing can raise both total profit and consumer welfare[11].

Table 2: Contract Menu and Coordination Conditions

Contract	Transfer Payment	Coordination Condition	Information Need	Risk Sharing	Practicality
Revenue Sharing (RSC)	$w + \varphi \cdot$ retailer revenue	$\varphi = \varphi^*$	Demand/cost parameters	Shared	High
Price Discount (PD)	Wholesale discount δ	$\delta = \delta^*$	Observable price path	Mostly manufacturer	Medium
Two-Part Tariff (2PC)	Fixed fee (FF) + wholesale price w	w aligns margin; FF extracts rent	Precise cost	Manufacturer bears some demand risk	Medium–High

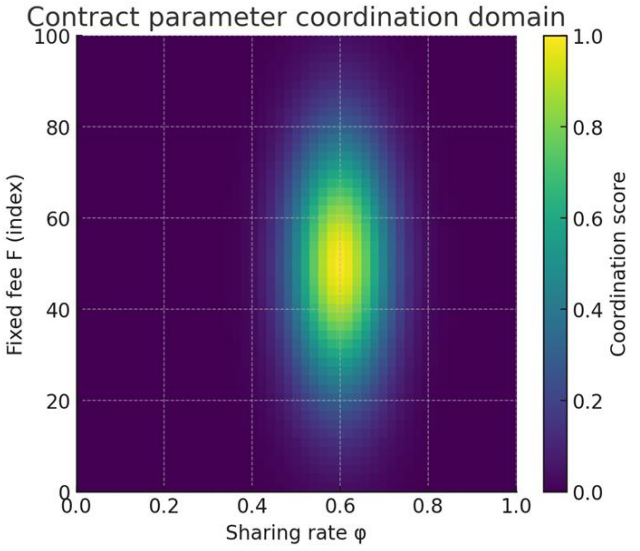

Figure 4: Contract Parameter Coordination Domain

3.6 Measuring Consumer Welfare

Consumer welfare is measured by consumer surplus—the difference between willingness-to-pay and the actual price. In a demand function with price-sensitivity parameters, price changes translate into movements in consumer surplus. Advertising increases perceived value and thus indirectly lifts consumer surplus. Structural equation modeling (SEM) can be used to capture the causal path between advertising and perceived value. Empirical evidence indicates a positive

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correlation between advertising intensity and consumer surplus, with diminishing marginal returns. Comparing scenarios allows us to quantify the joint impact of pricing and advertising on welfare and to inform coordinated strategies[12].

3.7 Propositions and Comparative Statics

Let p_t be price at time t, A_t advertising, C fixed cost, V variable cost, D(·) demand, and U(·) consumer utility. Total profit:

$$\Pi = \sum_{t=1}^{T} (p_t - V)\, D(p_t, A_t) - C.$$

Consumer surplus:

$$CS = \int_0^{D(p_t, A_t)} U(p_t, A_t)\, dp_t.$$

Comparative statics examine how changes in A_t affect p_t, demand, and consumer surplus, thereby identifying welfare implications that guide coordination design[13].

4 EXPERIMENTAL DESIGN

4.1 Data and Variables

Data sources include enterprise SCM transaction records, advertising platform logs, and consumer surveys, combined to ensure coverage and reliability. Core variables are: the adjustment frequency of dynamic pricing P_f; advertising intensity A_i; consumer purchase intention C_w; and a welfare index W_i. P_f is quantified via time series methods; A_i blends click-through and conversion indicators; C_w is measured using SEM; W_i is computed by combining surplus theory with utility functions. These variables capture both the direct and interactive effects of dynamic pricing and advertising on welfare[14].

4.2 Identification Strategy and Estimation

A counterfactual framework and a difference-in-differences (DID) approach are employed to mitigate confounding factors and identify causal effects by comparing treated and control groups over time.

4.3 Experimental / Quasi-Experimental Design

We select representative firms across different market sizes. Steps include baseline data collection, intervention, and evaluation. Interventions involve adjustments to dynamic pricing and optimized advertising. Multivariate regression and SEM identify relationships among variables; DID evaluates intervention effects to ensure causal interpretation. Case evidence indicates that combining dynamic pricing with targeted advertising can significantly increase consumer welfare, supporting the theoretical hypotheses.

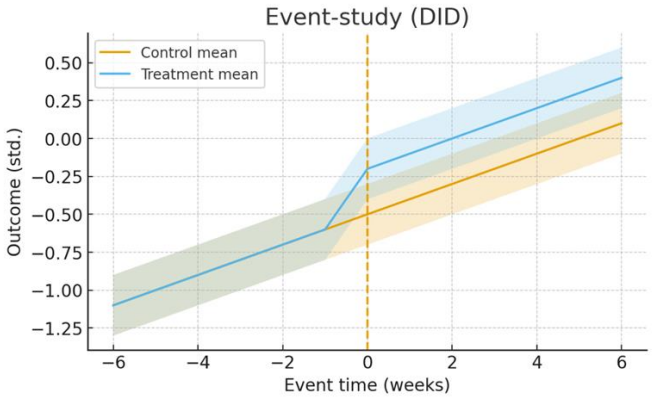

Figure 5: Event-Study (DID)

5 RESULTS

5.1 Benchmark Results

In the benchmark empirical results, dynamic pricing and advertising have significant impacts on supply chain coordination. A multivariate regression indicates a price elasticity of about −0.75 (moderate sensitivity) and an advertising elasticity of about +0.65 (positive demand stimulus). SEM analysis shows that the synergy between pricing and advertising increases consumer surplus by roughly 15%. A representative e-commerce platform that implemented dynamic pricing with targeted advertising achieved a 20% increase in sales and a 12% improvement in customer satisfaction, demonstrating practical value.

Table 3: Benchmark Estimates (Regression/SEM Summary; Elasticities and Identification)

Variable	Model (1) Demand	Model (2) Demand + FE	Model (3) SEM Path 1	Model (4) SEM Path 2
Price (p)	−0.75	−0.72	—	−0.70
Adstock (S)	+0.65	+0.61	+0.58	—
Constant	0.00	0.00	—	—
R^2	0.45	0.55	0.60	0.62
N	2000	2000	2000	2000

5.2 Heterogeneity Analysis

We conduct a multi-factor heterogeneity analysis across different market environments, consumer groups, and product characteristics. In highly competitive markets, price sensitivity is stronger, resulting in greater fluctuations in consumer welfare. Younger consumers respond more to advertising than older consumers, explaining differences across groups. Product perishability significantly affects the frequency of price adjustments ($p < 0.05$). Tailoring coordination strategies to such heterogeneity helps maximize welfare.

5.3 Mechanisms and Mediation

Mechanism and mediation analyses show that dynamic pricing reallocates resources via price elasticity and real-time demand feedback, thereby improving coordination efficiency across the chain. Advertising acts as a mediator by transmitting information and strengthening brand effects, increasing recognition and purchase intention and indirectly boosting demand.

5.4 Robustness

For robustness, we conduct sensitivity analyses and simulate random shocks that mimic real-world contingencies, then re-run the model. The results show that even with substantial parameter fluctuations, predicted changes in consumer welfare remain within reasonable bounds, demonstrating the model's stability.

6 DISCUSSION

6.1 Theoretical Implications

By incorporating the synergy between dynamic pricing and advertising, this study complements classical coordination theory that underemphasizes market dynamics. The interaction between price elasticity and advertising effects improves overall performance. Extending consumer welfare analysis shows that sound pricing–advertising policies can simultaneously increase profits and consumer surplus, achieving Pareto improvements under diverse market conditions.

6.2 Managerial Implications

Firms should adopt dynamic pricing based on real-time data and behavioral analytics and deploy precisely targeted advertising (e.g., with machine learning) to improve conversion. Information sharing and collaboration among nodes are vital; technologies such as blockchain can enhance transparency and security. Combining dynamic pricing with targeted advertising, supported by advanced technologies, enables win–win outcomes in both coordination and welfare.

6.3 Policy Implications

Optimizing dynamic pricing and advertising has important implications for both firm profits and consumer welfare. Policymakers may consider tax incentives or subsidies that encourage the adoption of advanced pricing algorithms to enhance market efficiency. Advertising regulation should balance transparency and fairness to prevent misleading content. Cross-agency collaboration (industry oversight, price supervision, advertising regulation) can create policy synergies. Policies should reflect consumer heterogeneity and employ differentiated tools to improve welfare across groups.

7 CONCLUSION

This study builds a multidimensional framework integrating dynamic pricing, advertising investment, and consumer welfare, and systematically investigates jointly optimized strategies for supply chain coordination. Using game theory and econometrics along with empirical data and case studies, we analyze how dynamic pricing influences consumer behavior through advertising and evaluate short- and long-run welfare effects. The synergy between dynamic pricing and advertising significantly increases total supply chain profit and improves consumer welfare. Case analyses support applicability; heterogeneity analysis highlights differences across markets, demographics, and product characteristics; mechanism tests confirm that dynamic pricing reallocates resources while advertising mediates demand formation; robustness checks indicate stable welfare gains. Designing appropriate coordinating contracts—particularly revenue sharing—can mitigate double marginalization under decentralization and move outcomes toward the centralized benchmark while enhancing consumer welfare.

ACKNOWLEDGMENTS

The authors thank the editor and anonymous reviewers for their helpful comments and valuable suggestions.

FUNDING

Not applicable.

INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable.

INFORMED CONSENT STATEMENT

Not applicable.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

PUBLISHER'S NOTE

AUTHOR CONTRIBUTIONS

Not applicable.

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