Hindawi
Complexity
Volume 2021, Article ID 5588724, 11 pages
https://doi.org/10.1155/2021/5588724

*Research Article*

# Customer Knowledge Enabled Innovation: Analyzing Pricing-Promotion Coordination Mechanism

**Guanbing Zhao,[1] Yangyang Qiu,[1] Muhammad Imran ,[2,3] and Fazal Manan[4]**

[1]*School of Management, Jiangsu University, Zhenjiang 212013, Jiangsu, China*
[2]*Faculty of Management Sciences, ILMA University, Karachi, Pakistan*
[3]*School of Finance & Economics, Jiangsu University, Zhenjiang 212013, Jiangsu, China*
[4]*Department of Management Sciences, Bacha Khan University, Charsadda, Khyber Pakhtunkhwa, Pakistan*

Correspondence should be addressed to Muhammad Imran; imran@ujs.edu.cn

Received 6 March 2021; Revised 8 May 2021; Accepted 13 June 2021; Published 21 June 2021

Academic Editor: Lei Xie



Pricing and promotion are two important decisions during the market launch of new consumer electronics products. Nowadays, the pricing and promotion of consumer electronic products are often not made separately but at the same time. This study focuses on the pricing-promotion coordination mechanism of a secondary supply chain of new consumer electronics products (which consists of a manufacturer and a seller). Price and the degree of promotion together affect the demand for products. Manufacturers give sellers a sales target. Manufacturers and sellers set prices and promotions separately, introduce repurchase penalty joint contracts, and establish supply chain profit models to compare and analyze optimal pricing, promotion efforts, and maximum profit of supply chains under different decision-making situations. We prove that the repurchase penalty joint contract can coordinate the supply chain under the assumptions of a single-period game and a multiperiod repeated game. The results show that under the repurchase penalty joint contract, when manufacturers and sellers choose high prices and high promotions at the same time, the supply chain of new consumer electronics products has the largest profit. Finally, numerical experiments are conducted to study the influence of parameters on optimal decision-making and supply chain profits.

## 1. Introduction

China is the world's largest consumer, producer, and exporter of consumer electronic products. With the continuous escalation of Sino-US trade frictions, as the world's largest producer and exporter of consumer electronics products, China's export of consumer electronics products will inevitably be affected. According to statistics from China International Capital Corporation, China's exports to the United States are mainly machinery, equipment, and instruments, which are mainly home appliances, electronics, and other categories according to classification, accounting for 48% of the total exports [1]. On the one hand, in the process of Sino-US trade frictions, consumer electronic products are bound to become part of the US high tariffs. On the other hand, the rapid iteration speed of consumer electronics products has intensified competition in the domestic market, such as the double launch of new models of Apple mobile phones a year. China's consumer electronics industry is struggling to survive under the dual squeeze of fierce competition in the domestic market and constant external Sino-US trade frictions. Therefore, designing an effective pricing and promotion coordination mechanism in the early stage of the advent of new consumer electronics products can effectively reduce the impact of Sino-US trade frictions and enable new consumer electronics products to increase revenue steadily, which is of great significance to upstream and downstream enterprises in the supply chain.

Existing new product supply chain research mainly focuses on the allocation of new product supply chain, risk assessment, new product development performance, and channel efficiency, but few scholars have specifically studied the issue of the new product pricing-promotion mechanism. For example, Clark et al. [1] and Handfield and Ragatz [2] studied the selection of suppliers and the development of new products. There are also some scholars studying the diffusion of new products. Amini et al. [3] used agent modeling, and simulation methods are based on three different supply chain production-sales strategies to study their impact on the diffusion of new products. Scholars like Gutierrez and Xiuli [4] studied the interaction between manufacturers and sellers in the innovative durable goods supply chain. Chiang [5] studied the impact of dynamic pricing strategies on the efficiency of supply chain channels in both the centralization and decentralization of the new product supply chain. Considering that, it is more appropriate to the demand form of the new products expected in this article. I specially refer to the demand form of new products in study by Lariviere and Padmanabhan [6] and Ray [7], that is, prices and promotion efforts jointly affect the demand for new products.

In the consumer electronics industry, new products are the key to a company's market leadership; in addition, pricing and promotion are key factors for new products to enter the market successfully. Appropriate pricing directly affects product demand. For example, Apple's iPhone7 Red Special Edition has become the shortest-lived mobile phone in Apple's series of mobile phones because of its high pricing and poor sales. In addition, under the premise that there is no substantial breakthrough in new consumer electronics technology, some effective promotions that do not affect the selling price also have a great impact on the demand for new products, such as the hunger marketing strategies of Apple and Xiaomi and various advertising of consumer electronics manufacturers. From the perspective of new product pricing and promotion decision-making research, domestic and foreign research mainly focuses on two aspects. First, research on the optimal pricing and promotion strategies of new products when there are different market segments [8–11] studied the decision-making of pricing and promotion efforts in a multistage supply chain. Liu et al. [12] studied the impact of promotion efforts under dual channels on the profits of manufacturers and retailers and concluded that only synergy between the upstream and downstream of the supply chain can improve promotion efficiency. Game theory has been very successfully applied in many fields [13, 14]. In supply chain research, game theory methods are widely used. Zamarripa et al. [15] applied game theory to industrial SCs and study solutions to maximize total profit under Nash equilibrium.

In the early stage of new consumer electronics products entering the market, this study proves that the repurchase penalty joint contract can effectively coordinate the secondary supply chain and proposes the optimal pricing-promotion strategy of the supply chain manufacturer-seller. The remaining content of the article is arranged as follows: Section 2 describes the problem and establishes basic models under different propositions and obtains the optimal price and optimal promotion degree in different situations. Third section presents the empirical analysis of the study, and fourth section further analyzes the influence of parameters on decision-making and the overall profit of the supply chain through numerical experiments. The last section concludes the study and presents future research directions.

## 2. Model Construction

*2.1. Problem Statement.* This article considers a secondary supply chain composed of a manufacturer and a seller. The manufacturer supplies a new consumer electronics product to the seller. Assuming that both parties are independent decision makers, the decision goal is to maximize the overall profit of the supply chain. Due to the short life cycle and single periodicity of consumer electronic products, inventory-related costs are less dependent on product output, order quantity, and order frequency, while pricing and promotional efforts have seriously affected demand. Therefore, in order to quickly open the market and increase the overall profit of the new product supply chain to maximize the profit, it is particularly important for manufacturers and sellers of the new product supply chain to make a strong pricing-promotion coordinated combination decision.

*2.2. Basic Assumptions*

(1) This type of new products is no different from traditional consumer electronic products in terms of supply, sales channels, and target groups. There are innovations in functions, but there is no essential difference.

(2) Both manufacturers and sellers are rational economic people

(3) All new products of this type produced by the manufacturer are distributed to the seller, and the manufacturer's own production capacity can cope with emergencies such as a surge in demand.

*2.3. Related Symbols*

$P_1$: unit wholesale price, which is the manufacturer's decision variable and the seller's acquisition cost

$P_2$: unit retail price, that is, the seller's decision variable

$P_3$: the seller has not reached the sales target to reduce the price for promotion

$C_1$: manufacturer unit production cost

$C_2$: manufacturer's overall R&D cost

$e_1$: manufacturer's promotion effort level

$e_2$: sales promotion effort level

The manufacturer wholesales to the seller at the price $P_1$, and the seller sells it at the retail price $P_2$ ($P_2 \geq P_1$). The manufacturer's unit production cost is $C_1$, and the overall R&D cost $C_2 = (q * R^2)/2$ ($q$ is the R&D cost elasticity and $R$ is the innovation level). The manufacturer determines the unit promotion cost $h_1$, and the seller determines the unit promotion cost $h_2$ ($h_1$, $h_2 \geq 0$), and the price reduction promotion price is $P_3$ ($P_2 \geq P_3 \geq P_1$). The demand for new products is related to wholesale prices, retail prices, and promotion costs. This article uses the market demand function: $f(x) = a - k_1P_1 - k_2P_2 + e_1 + e_2$, where $a$ represents the predicted sales scale of new electronic products, $K_1$ ($K_1 > 1$) represents the wholesale price elasticity, and $K_2$ ($K_2 > 1$) is the retail price elasticity of commodities. The cost required for the promotion effort level of manufacturers and sellers is expressed by the following quadratic function:

$$\begin{aligned} h_1 &= \frac{\varphi e_1^2}{2}, \\ h_2 &= \frac{\varphi e_1^2}{2}, \quad \varphi > 0. \end{aligned} \tag{1}$$

Suppose $f(x)$ is the sales target given by the manufacturer. Assuming the manufacturer's profit is $\Pi_1$ and the seller's profit is $\Pi_2$, the expression is as follows:

$$\begin{aligned} \Pi_1 &= f(x) * (P_1 - C_1) - h_1 - C_2, \\ \Pi_2 &= f(x) * (P_2 - P_1) - h_2. \end{aligned} \tag{2}$$

The expression of the total profit of the supply chain, which is the sum of the profit of the manufacturer and the seller, is

$$\Pi = (P_2 - C_1) * f(x) - h_1 - h_2 - C_2. \tag{3}$$

It is assumed here that $K_2 * \varphi > 0$, that is, market demand is more sensitive to retail price or promotion effort cost. For consumer electronic products, retail prices or promotions are bound to affect market demand.

*2.4. Model Construction and Model Resolution.* In order to find the best supply chain pricing-promotion combination strategy, considering that the repurchase penalty joint contract can effectively coordinate the supply chain under the situation of uncertain market demand, this section specially proposes the repurchase penalty joint contract and introduces that the unit penalty price is $m$ and the unit reward price is $n$ (under the contract, the manufacturer sets a sales target a according to the forecast (requires the seller to sell out) and sells the product to the seller at the wholesale price $P_1$, and the seller sets the retail price $P_2$ by himself. If the seller cannot achieve the sales target, the manufacturer will repurchase the part that exceeds the market demand at the wholesale price $P_1$ and punish it; if the sales target is achieved, the difference will be rewarded according to the amount of the difference). The specific decision is made according to the game behavior and actual situation of the manufacturer and the seller.

*Case 1.* $a < f(x)$

(1) The seller follows the repurchase penalty contract. At this time, the profits of the manufacturer, seller, and supply chain are as follows:

$$\begin{aligned} \Pi_1 &= a * (P_1 - C_1) + [f(x) - a] * (P_1 - m) - C_2 - h_1, \\ \Pi_2 &= a * (P_2 - P_1) + [f(x) - a] * m - h_2, \\ \Pi_A^* &= a * (P_2 - C_1) - P_1[f(x) - a] - C_2 - h_1 - h_2. \end{aligned} \tag{4}$$

Then, the optimal decision problem under this condition is that manufacturers and sellers choose appropriate $P_1$, $P_2$ and promotion efforts $e_1$, $e_2$ to maximize the overall return of the supply chain, that is, the optimal decision is the optimal solution of the following optimization model:

$$\operatorname{Max} P_2 \geq P_1 \Pi(P_2, e_1, e_2). \tag{5}$$

**Proposition 1.** *The optimal solution for the seller to follow the repurchase penalty contract is* $\begin{cases} P_{1(A)}^* = (a/k_2), \\ P_{2(A)}^* = (a/k_2\varphi), \\ e_{1(A)}^* = (-2a(k_1\varphi - 1)/k_2^2\varphi), \\ e_{2(A)}^* = (a/k_2\varphi). \end{cases}$

*Proof.* In order to verify whether the total profit $\prod$ of the supply chain can achieve the maximum value, a Hessian matrix $G_1$ is established:

$$G_1 = \begin{bmatrix} -2k_1 & -k_2 & 1 & 1 \\ -k_2 & 0 & 0 & 0 \\ 1 & 0 & -\varphi & 0 \\ 1 & 0 & 0 & -\varphi \end{bmatrix}. \tag{6}$$

From the value of matrix $G_1 = -K_2^2\varphi^2 < 0$, it is easy to verify that $\Pi$ ($P_1$, $P_2$, $e_1$, $e_2$) is a strictly concave function, so the optimal solution of problem (5) satisfies $\begin{cases} (\partial\Pi/\partial P_1) = 0, \\ (\partial\Pi/\partial P_2) = 0, \\ (\partial\Pi/\partial e_1) = 0, \\ (\partial\Pi/\partial e_2) = 0. \end{cases}$ Thus, the optimal $P_1^*, P_2^*, e_1^*, e_2^*$ can be obtained as

$$\begin{cases} P_{1(A)}^* = \dfrac{a}{k_2}, \\ P_{2(A)}^* = \dfrac{a}{k_2\varphi}, \\ e_{1(A)}^* = \dfrac{-2a(k_1\varphi - 1)}{k_2^2\varphi}, \\ e_{2(A)}^* = \dfrac{a}{k_2\varphi}. \end{cases} \tag{7}$$

Substituting (7) into (5), the maximum profit of the supply chain based on the repurchase penalty contract is

$$\Pi_A^* = \frac{8k_1a^2\phi + k_2^2a^2 + 4k_2a^2 - 4a^2 - 4k_1^2a^2\phi^2 - 2k_1k_2^2a^2\phi - 4k_1k_2a^2\phi}{2k_2^4\phi}. \tag{8}$$

(2) The seller does not follow the repurchase penalty contract; the seller does not return the product and reduces the price by themself. At this time, the profit of the manufacturer, seller, and supply chain is as follows:

$$\Pi_1 = a * \left(P_1 - C_1\right) - h_1 - C_2, \tag{9}$$

$$\begin{aligned} \Pi_2 &= a * \left(P_2 - P_1\right) + [a - f(x)] * \left(P_1 - P_3\right) - h_2, \\ \Pi_B^* &= a * \left(P_2 - C_1\right) + [a - f(x)] * \left(P_1 - P_3\right) - h_1 - h_2 - C_2. \end{aligned} \tag{10}$$

Then, the optimal decision problem under this condition is that manufacturers and sellers choose appropriate $P_1$, $P_2$ and promotion efforts $e_1$, $e_2$ to maximize the total revenue of the supply chain, that is, the optimal decision is the optimal solution of the following optimization model:

$$\operatorname{Max} P_2 \geq P_1 \Pi\left(P_2, e_1, e_2\right). \tag{11}$$

□

**Proposition 2.** *The optimal solution for the seller to follow the repurchase penalty contract is* $\begin{cases} P_{1(B)}^* = (k_2P_3 - a/k_2), \\ P_{2(B)}^* = (a/k_2\varphi), \\ e_{1(B)}^* = (2a + 2ak_1\varphi - k_1k_2P_3\varphi/k_2^2\varphi), \\ e_{2(B)}^* = (a/k_2^2\varphi). \end{cases}$

*Proof.* In order to verify whether the total profit $\prod$ of the supply chain can achieve the maximum value, a Hessian matrix $G_2$ is established:

$$G_2 = \begin{bmatrix} 2k_1 & k_2 & -1 & -1 \\ 0 & k_2 & 0 & 0 \\ -1 & & -\varphi & 0 \\ -1 & & 0 & -\varphi \end{bmatrix}. \tag{12}$$

From the value of matrix $G_2 = -K_2^2\,\varphi^2 < 0$, it is easy to verify that $\Pi$ $(P_1,\ P_2,\ e_1,\ e_2)$ is a strictly concave function, so the optimal solution of problem (9) satisfies

$$\begin{cases} \dfrac{\partial \Pi}{\partial P_1} = 0, \\ \dfrac{\partial \Pi}{\partial P_2} = 0, \\ \dfrac{\partial \Pi}{\partial e_1} = 0, \\ \dfrac{\partial \Pi}{\partial e_2} = 0. \end{cases} \tag{13}$$

Thus, the optimal $P_1^*, P_2^*, e_1^*, e_2^*$ can be obtained as

$$\begin{cases} P_{1(B)}^* = \dfrac{k_2P_3 - a}{k_2}, \\ P_{2(B)}^* = \dfrac{a}{k_2\varphi}, \\ e_{1(B)}^* = \dfrac{2a + 2ak_1\varphi - k_1k_2P_3\varphi}{k_2^2\varphi}, \\ e_{2(B)}^* = \dfrac{a}{k_2^2\varphi}. \end{cases} \tag{14}$$

The maximum profit of the supply chain at this time is

$$\begin{aligned} \Pi_B^* = {} & \frac{4k_1^2k_2\varphi^2P_3 + 4ak_1k_2\varphi P_3 + 2a^2k_1k_2^2\varphi + 4a^2k_1k_2\varphi + a^2k_2^2 + 4a^2k_2}{2k_2^4\varphi} \\ & - \frac{k_1^2k_2^2\varphi^2P_3^2 + 4k_1^2a^2\varphi^2 + 2k_1k_2^3P_3\varphi + 2k_1k_2^2P_3\varphi}{2k_2^4\varphi} + \frac{8a^2k_1\varphi + 4a^2 + 2C_1ak_2^4\varphi + 2C_2k_2^4}{2k_2^4\varphi}. \end{aligned} \tag{15}$$

(3) In order to ensure that the sales price will not fluctuate significantly in the next cycle, the seller will make a decision of neither returning the product nor reducing the price. At this time, the profit of the manufacturer, seller, and supply chain is as follows:

$$\begin{aligned} \Pi_1 &= a * \left(P_1 - C_1\right) - h_1 - C_2, \\ \Pi_2 &= a * \left(P_2 - P_1\right) - [a - f(x)] * P_1 - h_2, \\ \Pi_C^* &= a * \left(P_2 - C_1\right) - [a - f(x)] * P_1 - C_2 - h_1 - h_2. \end{aligned} \tag{16}$$

Under the same conditions, the optimal decision problem is that manufacturers and sellers choose appropriate $P_1$, $P_2$ and promotion efforts $e_1$, $e_2$ to maximize the overall revenue of the supply chain, that is, the optimal decision is the optimal solution of the following optimization model:

$$\text{Max}\, P_2 \geq P_1 \Pi\left(P_2, e_1, e_2\right). \tag{17}$$

□

**Proposition 3.** *The optimal solution for the seller to follow the repurchase penalty contract is* $\begin{cases} P^*_{1(C)} = (a/k_2), \\ P^*_{2(C)} = (a/k_2\varphi), \\ e^*_{1(C)} = (-2a(K_1\varphi - 1)/k_2^2\varphi), \\ e^*_{2(C)} = (a/k_2\varphi). \end{cases}$

*Proof.* In order to verify whether the total profit $\prod$ of the supply chain can achieve the maximum value, a Hessian matrix $G_3$ is established:

$$G_3 = \begin{bmatrix} -2k_1 & k_2 & 1 & 1 \\ 0 & -k_2 & 0 & 0 \\ 1 & 0 & -\varphi & 0 \\ 1 & 0 & & -\varphi \end{bmatrix}. \tag{18}$$

From the value of matrix $G_3 = K_2^2\varphi^2 < 0$, it is easy to verify that $\Pi\ (P_1, P_2, e_1, e_2)$ is a strictly concave function, so the optimal solution of problem (17) satisfies

$$\begin{cases} \dfrac{\partial \Pi}{\partial P_1} = 0, \\ \\ \dfrac{\partial \Pi}{\partial P_2} = 0, \\ \\ \dfrac{\partial \Pi}{\partial e_1} = 0, \\ \\ \dfrac{\partial \Pi}{\partial e_2} = 0. \end{cases} \tag{19}$$

Thus, the optimal $P_1^*, P_2^*, e_1^*, e_2^*$ can be obtained as

$$\begin{cases} P^*_{1(C)} = \dfrac{a}{k_2}, \\ \\ P^*_{2(C)} = \dfrac{a}{k_2\varphi}, \\ \\ e^*_{1(C)} = \dfrac{-2a\left(K_1\varphi - 1\right)}{k_2^2\varphi}, \\ \\ e^*_{2(C)} = \dfrac{a}{k_2\varphi}. \end{cases} \tag{20}$$

At this time, the maximum profit of the supply chain is

$$\Pi_C^* = \frac{8k_1a^2\phi + k_2^2a^2 + 4k_2a^2 - 4a^2 - 4k_1^2a^2\phi^2 - 2k_1k_2^2a^2\phi - 4k_1k_2a^2\phi - 2k_2^4a\phi\left(C_1 + C_2\right)}{2k_2^4\phi}. \tag{21}$$

**Proposition 4.** *In Case 1,* $\Pi_A^* > \Pi_B^* > \Pi_C^*$.

*Proof.* Judging from the expressions of $\Pi_A^*$ and $\Pi_B^*$, $\Pi_A^* - \Pi_B^* = [a - f(x)] * P_3 > 0$ always holds according to the conditions. Judging from the expressions of $\Pi_B^*$ and $\Pi_C^*$, $\Pi_B^* - \Pi_C^* = [a - f(x)] * (2P_1 - P_3) > 0$ always holds according to the conditions. It can be concluded that when the sales target set by the manufacturer is less than the final sales volume, $\Pi_A^* > \Pi_B^* > \Pi_C^*$. □

*Case 2.* $a > f(x)$, that is, when the final sales volume is greater than the predicted market demand, regardless of whether the initial seller chooses to comply with the repurchase penalty joint contract, the profit change only exists in the manufacturer and the seller, and has no impact on the profit of the supply chain. Supply chain profits are as follows:

$$\begin{aligned}\Pi_1 &= a * (P_1 - C_1) - [f(x) - a] * n - h_1 - C_2,\\ \Pi_2 &= a * (P_2 - P_1) + [f(x) - a] * n - h_2,\\ \Pi_D^* &= f(x) * (P_2 - C_1) - C_2 - h_1 - h_2.\end{aligned} \tag{22}$$

At this time, under this condition, $P_1$ has no substantial impact on the profit of the supply chain and $k_1 > 1$ which is regarded as a constant. Then, the optimal decision-making problem becomes that the manufacturer chooses the appropriate $e_1$ and the seller chooses the appropriate $P_2$ and the promotion effort $e_2$ to maximize the overall return of the supply chain, that is, the optimal decision is the optimal solution of the following optimization model:

$$\operatorname{Max} P_2 \geq P_1 \Pi(P_2, e_1, e_2). \tag{23}$$

**Proposition 5.** *The optimal $P_2^*, e_1^*, e_2^*$ in Case 2 are*

$$\begin{cases} P_{2(D)}^* = \dfrac{a - C_1K_2 - K_1P_1}{2(k_2\varphi - 1)},\\[2ex] e_{1(D)}^* = \dfrac{a\varphi + C_1K_2\varphi - 2C_1 - K_1P_1\varphi}{2(k_2\varphi - 1)},\\[2ex] e_{2(D)}^* = \dfrac{a - C_1K_2 - K_1P_1}{2(k_2\varphi - 1)}.\end{cases} \tag{24}$$

*Proof.* In order to verify whether the total profit $\prod$ of the supply chain can achieve the maximum value, a Hessian matrix $G_4$ is established:

$$G_4 = \begin{bmatrix} -2K_2 & 1 & 1\\ 1 & -\phi & 0\\ 1 & 0 & -\phi \end{bmatrix}. \tag{25}$$

From the value of matrix $G_4 = 2\phi - 2K_2\varphi^2$, it is easy to verify that $\Pi(P_1, P_2, e_1, e_2)$ is a strictly concave function, so the optimal solution of problem (26) satisfies $\begin{cases}(\partial\Pi/\partial P_2) = 0,\\ (\partial\Pi/\partial e_1) = 0,\\ (\partial\Pi/\partial e_2) = 0.\end{cases}$ Thus, the optimal $P_2^*, e_1^*, e_2^*$ can be obtained as

$$\begin{cases} P_{2(D)}^* = \dfrac{a - C_1K_2 - K_1P_1}{2(k_2\varphi - 1)},\\[2ex] e_{1(D)}^* = \dfrac{a\varphi + C_1K_2\varphi - 2C_1 - K_1P_1\varphi}{2(k_2\varphi - 1)},\\[2ex] e_{2(D)}^* = \dfrac{a - C_1K_2 - K_1P_1}{2(k_2\varphi - 1)}.\end{cases} \tag{26}$$

Substituting (8) into (23), the maximum profit of the supply chain at this time is

$$\begin{aligned}\Pi_D^* = &\frac{C_1K_2^3\left(4\varphi - 2C_1^2K_2^3 - C_1^2K_2^2\varphi^3 - 4C_1^2K_2^2 + C_1^2K_2^2\varphi + 6C_1^2K_2^2 + 4C_1^2K_2\varphi^2 + 12C_1^2K_2\varphi\right.}{8(K_2\varphi - 1)^2}\\ &+ \frac{8C_1K_1K_2^2P_1\varphi^2 - 4C_1^2\varphi - 8C_1^2 - 4C_1K_1K_2^2P_1 + 2C_1K_1K_2P_1\varphi^3 + 4C_1K_1K_2P_1\varphi^2 - 14C_1K_1K_2P_1\varphi}{8(K_2\varphi - 1)^2}\\ &+ \frac{4C_1K_1K_2P_1 - 4C_1K_1P_1\varphi^2 - 4C_1K_1P_1\varphi + 8C_1K_1P_1 - 8C_1aK_2^2\varphi^2 + 4C_1aK_2^2 - 2C_1aK_2\varphi^3}{8(K_2\varphi - 1)^2}\\ &+ \frac{14C_1aK_2\varphi - 4C_1aK_2\varphi^2 - 4C_1aK_2 + 4C_1a\varphi^2 + 4C_1a\varphi - 8C_1a + 4K_1^2P_1^2K_2\varphi - 24K_1^2P_1^2K_2}{8(K_2\varphi - 1)^2}\\ &+ \frac{K_1^2P_1^2\varphi - K_1^2P_1^2\varphi^3 - 2K_1^2P_1^2 - 8K_1P_1aK_2\varphi + 4K_1P_1aK_2 + 2K_1P_1a\phi^3 - 2K_1P_1a\phi + 4K_1P_1a}{8(K_2\varphi - 1)^2}\\ &+ \frac{4a^2K_2\varphi - 2a^2K_2 - a^2\varphi^3 + a^2\varphi - 2a^2 - 8C_2K_2^2\varphi^2 + 16C_2K_2 - 8C_2}{8(K_2\varphi - 1)^2}.\end{aligned} \tag{27}$$

**Proposition 6.** *When the sales target set by the manufacturer is greater than the final sales volume, the supply chain profit under the repurchase penalty contract and the profit in the noncompliance contract are the same as $\Pi_D^*$, but for the manufacturer and the seller as a whole, it increases profits and enhances promotion enthusiasm, which is conducive to the manufacturer's next cycle of new product demand forecasts and promotion cost input by both parties, improves the success* *rate of new products on the market, and thereby increases the profit level of the entire supply chain.*

## 3. Numerical Analysis

In the previous section, we obtained the comparison results of supply chain profits under different pricing and promotion orders through theoretical analysis. In this section, we will use numerical analysis to explore the influence of wholesale price sensitivity coefficient $K_1$, retail price sensitivity coefficient $K_2$, and promotion effort cost coefficient $\varphi$ on optimal decision-making and the impact of supply chain profit $\Pi_A^*$. Here, the parameters of the new product supply chain are set as follows: $a = 1450$, $C_1 = 400$, and $C_2 = 30$.

*3.1. Wholesale Price Elasticity Coefficient $K_2$.* We set $K_1 = 4$, $\varphi = 0.1$, and $K_2$ to be 1, 2, 3, 4, 5, and 6, respectively. According to Figure 1, as $K_2$ increases, the wholesale price $P_1$, retail price $P_2$, promotion efforts, and supply chain profits are lower, and manufacturers and sellers are less willing to promote sales. The smaller $K_2$, the lower the wholesale price and retail price and the higher the promotion level. While manufacturers are adopting high-pricing and high-promotion decisions, sellers should also adopt higher-pricing and higher-promotion decision-making strategies to improve supply chain profits. The larger $K_2$ is, it is not good for the supply chain of new consumer electronics products.

*3.2. Promotional Effort Cost Coefficient $\varphi$.* We set $K_1 = 4$, $K_2 = 6$, and $\varphi$ takes 0.1, 0.2, 0.3, and 0.5, respectively. According to Figure 2 the larger $\varphi$, the lower the retail price and the promotion efforts of manufacturers and sellers because the higher the promotion cost, the less willing are manufacturers and sellers to promote sales, and sellers can only expand market demand by lowering retail prices. At the same time, as $\varphi$ increases, the optimal retail price $P_2$ under the repurchase penalty contract, the optimal promotion effort levels $e_1$ and $e_2$, and the profit of the entire supply chain will all become lower. This means that the larger $\varphi$, the more unfavorable the supply chain of new consumer electronics products.

In order to ensure the maximum profit of the new consumer electronics product supply chain, both parties in the supply chain should abide by the repurchase penalty joint contract and make both manufacturers and sellers adopt a coordination mechanism of high pricing and high promotion.

## 4. Long-Term Repeated Game Pricing-Promotion Decision Game

The above discussion only considers the situation of a single game. However, in the actual supply chain, there are multiple repeated games between manufacturers and sellers. The strategic choices of both parties in the supply chain are based on the results of the previous game. From a long-term perspective, in order for both parties in the supply chain to choose a pricing-promotion mechanism with high pricing and high promotion each time the game results, both manufacturers and retailers must have a certain spirit of contract while introducing a reasonable form of profit distribution. Assuming that the undistributed profit before the manufacturer's profit will be more than the profit after the distribution, it is very likely that the seller will choose not to comply with the contract in the second game stage, which will damage the overall profit of the supply chain. If the seller predicts this before the transaction, they will not choose to comply with the contract in the first game stage. At this time, both the manufacturer and the retailer will choose not to comply with the previously agreed contract. It can be seen that if there is a long-term lack of control measures, the profit of the supply chain will fluctuate greatly.

Considering that in a competitive market environment, the relationship between manufacturers and sellers in the supply chain is equal, so in order to seek the problem of maximizing the profits of the new product supply chain under the long-term repeated game (that is, both manufacturers and sellers choose high price and high promotion decision), we assume that the loss value of the party who does not comply with the contract is $M$ (including loss of reputation and increase in collective costs caused by work stoppage). The value of $M$ is much greater than the profit obtained by any party in the one-time game. Get a profit distribution plan that is acceptable to both parties and has a certain contractual nature; then, the distribution of profits is

$$\begin{aligned} a > f(x)t, \quad & \Pi_1 = \rho * \Pi_A^*, \\ & \Pi_2 = (1-\rho) * \Pi_A^*, \\ a < f(x)t, \quad & \Pi_1 = \rho * \Pi_D^*, \\ & \Pi_2 = (1-\rho) * \Pi_D^*. \end{aligned} \tag{28}$$

Let $i$ represent the number of stages in the repeated game between the two parties, and set the profit distribution factor of the $i^{\text{th}}$ stage as $\rho_i$. If the manufacturer chooses not to comply with the contract in the $n+1$ stage, considering the time value of funds, the manufacturer's discount rate for each stage is $j_1$. The discount rate of each stage of the seller is $j_2$, and the present value of the manufacturer's mincome at stage $n$ is

$$\Pi_1 = \sum_{i=1}^{n} \rho_i, \Pi_A^*\left(P_{1(A)}^*\right)\mu_1^j. \tag{29}$$

If the repurchase penalty contract is not complied with in the $n+1$ stage, then

$$\Pi_1^F = \sum_{i=1}^{n} \rho_i, \Pi_A^*\left(P_{1(A)}^*\right)\mu_1^j - M. \tag{30}$$

Present value of seller's earnings is

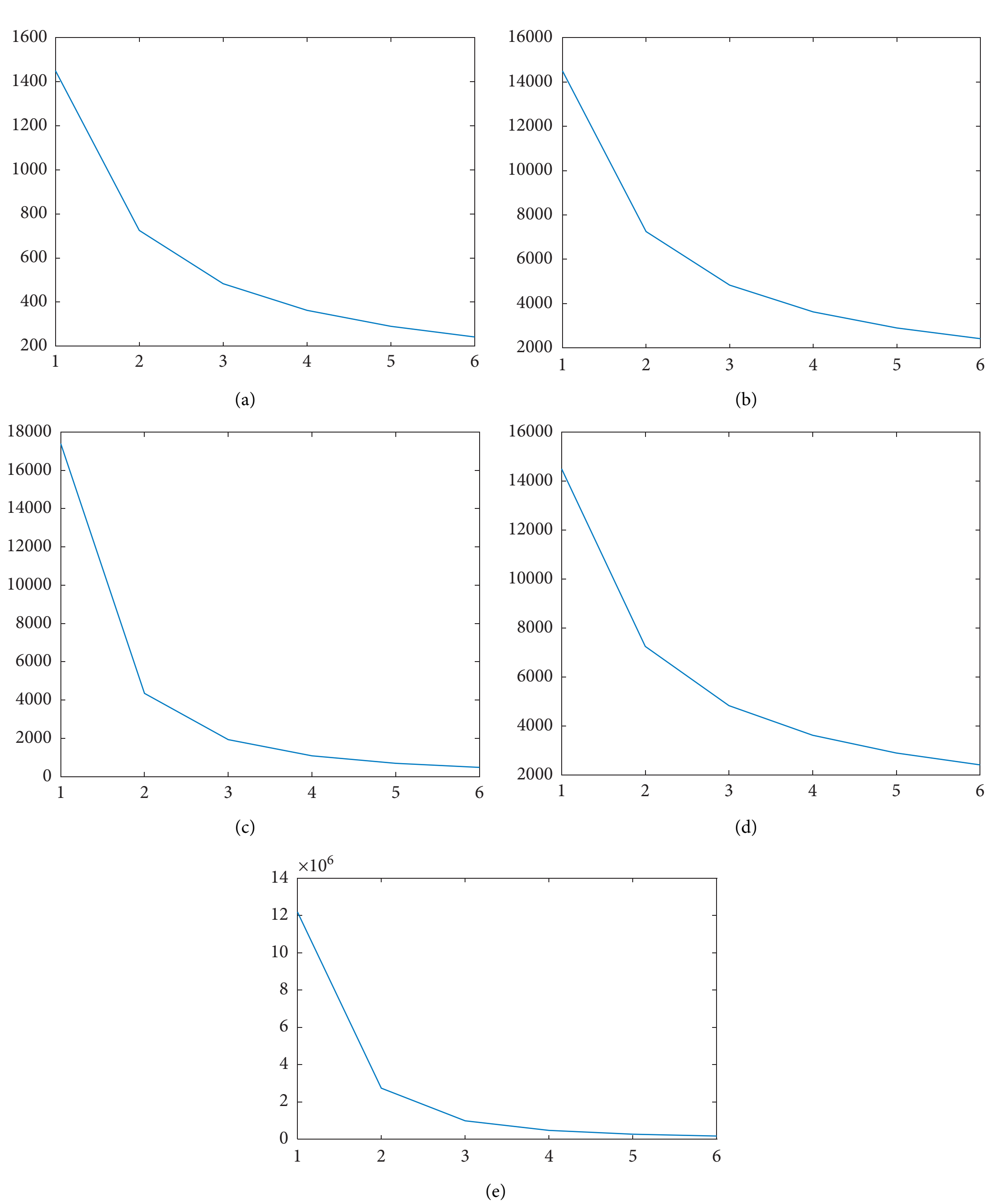


Figure 1: The influence of $K_2$ on optimal decision and optimal profit. (a) The influence of $K_2$ on the wholesale price $P_1$. (b) The influence of $K_2$ on the wholesale price $P_2$. (c) The influence of $K_2$ on the wholesale price $e_1$. (d) The influence of $K_2$ on the wholesale price $e_2$. (e) The influence of $K_2$ on optimal profit.

$$\Pi_2 = \sum_{i=1}^{n} \rho_i, \Pi_A^*\left(P_{2(A)}^*\right)\mu_2^j. \tag{31}$$

If the repurchase penalty contract is not complied with in the $n+1$ stage, then

$$\Pi_2^F = \sum_{i=1}^{n} \rho_i, \Pi_A^*\left(P_{2(A)}^*\right)\mu_2^j - M. \tag{32}$$

Obviously, once the manufacturer decides not to comply with the repurchase penalty joint contract, the manufacturer's profit will eventually be negative. Similarly, if the seller decides not to comply with the repurchase penalty joint contract for a certain period, the profit will eventually be negative. Therefore, in the repeated game, manufacturers and sellers need to comply with the repurchase penalty joint contract at each game stage is the only equilibrium result.

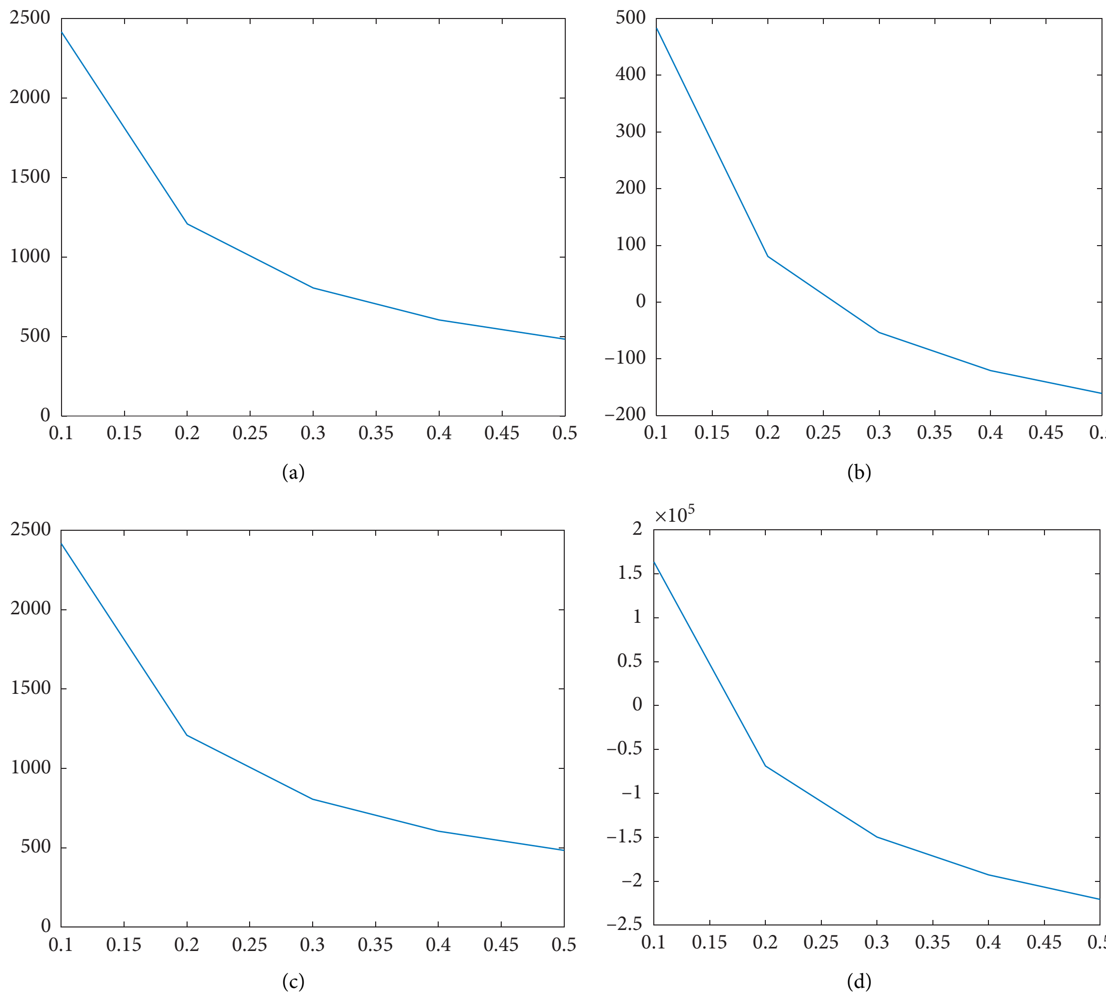


Figure 2: The influence of $\varphi$ on the optimal decision and optimal profit. (a) The influence of $\varphi$ on the retail price $P_2$. (b) The influence of $\varphi$ on the promotion effort level $e_1$. (c) The influence of $\varphi$ on the retail price $e_2$ (d) The influence of $\varphi$ on optimal profit.

## 5. Conclusion

The rapid rise of electronic technology with the development of social science and technology has greatly improved people's living standards. At present, consumer electronics products are lacking in innovation, and products are becoming more and more homogeneous. With the advent of the 5G era, a large number of homogenized new products have swarmed into the consumer electronics market. In order to compete for market share, competition between enterprises and even the supply chain is bound to be fierce. Price wars and sales promotion wars will emerge in endlessly, flooding every game cycle of sales. At this time, only by implementing appropriate pricing-promotion coordination strategies can companies gain a foothold in market competition. In the postepidemic era, in the case of different damages to the global supply chain, in order to ensure that the overall profit of the consumer electronics new product supply chain is optimal, adopting appropriate pricing-promotion coordination strategies and appropriate contracts have become the research focus.

This article mainly studies the coordination of the supply chain of new consumer electronics products and tries to explore a contract that can coordinate the supply chain of new consumer electronics products, introduces a repurchase penalty contract and seeks the most effective pricing-promotion mechanism under this contract, and finally maximizes the profits of the supply chain. In this article, demand is not only related to price but also affected by promotional efforts. We also compared the profit situation of the new consumer electronics product supply chain under the joint repurchase penalty under different decision-making situations and derived the profit function of the supply chain manufacturers and sellers under the long-term game, indicating that whether it is in the optimal equilibrium is a single-period game or a long-term game where manufacturers and sellers comply with the repurchase penalty joint contract. Finally, through numerical experiments, the influence of some parameters of the supply chain on decision-making and profit is analyzed. Through research, the results of this article are as follows:

(1) In situation 1, when the sales target set by the manufacturer is less than the final sales volume, Proposition 1, the supply chain profit of the seller under the repurchase penalty joint contract, is the largest, which is also in line with the seller's decision-making choice under actual circumstances. In situation 2, when the sales target set by the manufacturer is greater than the final sales volume, the supply chain profit under the supplier's compliance with the repurchase penalty contract and the profit under the noncompliance contract are both $\Pi_D^*$; but for both the manufacturer and the seller as a whole, it increases profits and enhances the enthusiasm for promotion, which is conducive to the manufacturer's next cycle of new product demand forecasts and promotion cost input by both parties, and improves the success rate of new products on the market, thereby increasing the profit level of the entire supply chain.

(2) When the contract parameters meet the given conditions and are within a certain range, the repurchase reward and punishment joint contract can realize the coordination of the new consumer electronics product supply chain. When repurchase rewards and punishments are based on joint contracts, both manufacturers and sellers should adopt a high-pricing and high-promotion strategy.

(3) Under the model of joint promotion by manufacturers and sellers, with the increase in production costs, manufacturers' promotion levels, and sellers' promotion efforts, wholesale and retail prices will rise accordingly. The relationship between the manufacturer's promotion level, seller's promotion effort level, and retail price depends on the value of $K_1$ and $K_2$.

*5.1. Future Research Direction.* On the basis of this article, future research can also be carried out from the following perspectives: (1) research on the coordination of the pricing-promotion mechanism of new consumer electronic products under other contracts. This article considers the repurchase penalty joint contract. In real life, companies may sign other contracts. Therefore, it is an interesting research topic to study the decision sequence under other contracts. (2) This article assumes that promotion is verifiable. In real life, sometimes promotion is not verifiable. It is an important topic to study the problem of new product supply chain coordination when promotion is not verifiable.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## Acknowledgments

The authors acknowledge the effort of the editor and anonymous reviewers who provided more insightful comments to improve this work. They also acknowledge the financial support of National Social Science Foundation Project (19FGLB012), Research on Coupling Mechanism and Performance Improvement of Crowd Creation Space Incubation Service Capability Jiangsu Provincial Social Science Foundation Project (18JD016), Research on the Logic Mechanism and Cultivation Strategy of High-Quality Development of Jiangsu Small and Microenterprise Double Innovation Base, and partial support by ILMA University, Karachi, Pakistan.

## References

[1] K. B. Clark, B. Chew, and T. Fujimoto, "Product development in the world auto industry," *Brookings Papers on Economic Activity*, vol. 3, pp. 729–781, 1987.

[2] R. B. Handfield, G. L. Ragatz, K. Peterson, and R. Monczka, "Involving suppliers in new product development," *California Management Review*, vol. 42, no. 1, pp. 59–82, 1999.

[3] M. Amini, M. Racer, T. Wakolbinger, and M. G. Nejad, "Alternative supply chain production sales policies for new product diffusion: an agent-based modeling and simulation approach," *European Journal of Operational Research*, vol. 216, no. 2, Article ID 301311, 2012.

[4] G. J. Gutierrez and H. Xiuli, "Lifecycle channel coordination issues in launching an innovative durable product," *Production and Operations Management*, vol. 20, no. 2, pp. 268–279, 2011.

[5] W. K. Chiang, "Supply chain dynamics and channel efficiency in durable product pricing and distribution," *Manufacturing & Service Operations Management*, vol. 14, no. 2, p. 3, 2012.

[6] M. A. Lariviere and V. Padmanabhan, "Slotting allowances and new product introductions," *Marketing Science*, vol. 16, no. 2, pp. 112–128, 1997.

[7] S. Ray, "An integrated innovative products and services. International economics," *Journal of Production*, vol. 95, no. 3, pp. 327–345, 2005.

[8] P.C. Jha, R. Cambini, P. Manik, and K. Chaudhary, "Optimal pricing and promotional effort control policies for market a new product growth in segmented market," *Yugoslav Journal of Operations Research*, vol. 25, no. 1, pp. 73–91, 2015.

[9] M. Imran, Y. Zhong, R. Yu, M. Wu, and H. C. Moon, "Nexus among foreign remittances and economic growth indicators in south Asian countries: an empirical analysis," *The Journal of International Trade & Commerce*, vol. 17, no. 1, pp. 263–275, 2021.

[10] T. Chernonog, T. Avinadav, and T. Ben Zvi, "Pricing and sales-effort investment under bicriteria in a supply chain of virtual products involving risk," *Operational Research European Journal of*, vol. 246, pp. 471–475, 2015.

[11] M. Imran, M. Wu, L. Zhang, Q. He, and A. Yar, "An empirical analysis of firm specific factors and equity premium: evidence from manufacturing sector of Pakistan," *Mathematical Problems in Engineering*, vol. 2020, Article ID 1346053, 9 pages, 2020.

[12] C. Liu, C. K. M. Lee, and K. L. Choy, "Sales effort deployment in decentralized dual channel distribution," *Industrial Management & Data Systems*, vol. 116, no. 4, pp. 821–837, 2016.
[13] C. Chen, G. Reniers, and N. Khakzad, "Cost-benefit management of intentional domino effects in chemical industrial areas," *Process Safety and Environmental Protection*, vol. 134, pp. 392–405, 2020.
[14] W. Mengyun, M. Imran, M. Zakaria, Z. Linrong, M. U. Farooq, and S. K. Muhammad, "Terrorism and political instability on equity premium: evidence from Pakistan," *Physica A: Statistical Mechanics and Its Applications*, vol. 492, pp. 1753–1762, 2018.
[15] M. A. Zamarripa, A. M. Aguirre, C. A. Méndez, and A. Espuña, "Improving supply chain planning in a competitive environment," *Computers & Chemical Engineering*, vol. 42, pp. 178–188, 2012.