

## Blockchain-enabled crypto-coordination mechanism in O2O era

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**Abstract:** An online-to-offline (O2O) coordination mechanism becomes inevitable to sustain profits or benefits for all the supply chain participants when a manufacturer introduces an online channel that competes with the offline channel of the retailer. We propose a crypto-coordination mechanism to alleviate O2O competition by delivering financial support to the retailer through the manufacturer's crypto-token reward to achieve Pareto results. The results indicate that the crypto-coordination mechanism mitigates O2O competition and benefits all supply chain participants. It promotes coordination through token rewards and ensures higher profits for all supply chain stakeholders to sustain competing channels. Notably, increasing the intensity of competition among channels drives higher profits, validating the effectiveness of the proposed coordination mechanism. The findings of this study deliver critical insights into the market dynamics under O2O competition. Additionally, they are of practical significance in enhancing coordination among competing channels. These insights contribute to literature and practice alike.

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**Keywords:** Blockchain; Crypto-tokens; Coordination; Supply chain; Online to Offline (O2O); E-commerce

### 1. INTRODUCTION

The unprecedented digital transformation that has gone hand in hand with the leap in e-commerce worldwide has ushered in an additional dimension to competition, known as online-to-offline (O2O) competition (Amrouche and Yan, 2016, Guan et al., 2023, Tsay and Agrawal, 2004). Such competition arises when a manufacturer introduces a channel to sell products directly to customers, competing with the existing retailers who sell the product offline. The importance of the domain derives from its ability to reshape customer behavior, competitive dynamics, and the retail ecosystem.

The existing research investigated various coordination mechanisms to eliminate the issues arising from O2O distribution. Such mechanisms have been based on revenue sharing, cost sharing, sales effort, and brand differentiation, among others, to establish coordination in the best interest of both the manufacturer and retailer (Amrouche and Yan, 2016, Guan et al., 2023, Tsay and Agrawal, 2004, Cattani et al., 2006, Yan et al., 2019). Despite the plethora of literature, notable research gaps demand attention to the effective implementation of these coordination mechanisms.

Firstly, one of the fundamental assumptions behind the coordination mechanisms, such as revenue sharing and profit sharing, is that both retailer and manufacturer have access to each other's product sales information. However, the remote storage of information by stakeholders results in information silos and asymmetry. The lack of transparency hinders trust and becomes a barrier to effectively implementing the coordination mechanisms.

Secondly, these coordination mechanisms are based on monetary incentives (e.g., cash). Especially in e-commerce, stakeholders are not uncommon to be geographically distributed/located across borders. However, such locational diversity limits monetary incentives from inflation, changing currency exchange rates, and regional government policies (or geopolitics), among others (Harish et al., 2023b, Harish et al., 2025). The perceived value loss can reduce long-term motivation for the retailers/participants.

The above research gaps lead to two research questions:

- (1) How can a coordination mechanism that satisfies the needs of O2O distribution, such as transparency and value protection/preservation, be set up?
- (2) Which parameters influence competition and profits when coordinating the competing channels?

This study aims to investigate a novel crypto-coordination mechanism based on blockchain technology using game theory. In the mechanism, the manufacturer delivers financial support to the retailer through crypto-tokens rewards for coordination, whereas the underlying blockchain technology brings transparency and trust to the sales information from individual channels. When information is shared and stored in a blockchain network, it becomes available for use by the internal supply chain stakeholders through a decentralized ledger (Harish et al., 2023a, Harish et al., 2021, Li et al., 2023, Li et al., 2025). The crypto-tokens have been the cornerstone for initiatives such as ICOs and the NFTs, driving Metaverses for their ability to represent ownership and hold immutable value (Harish et al., 2023a). We use crypto-tokens as the

reward given to the customer for their purchase through the online channel. The customer redeems the collected token rewards for future purchases from the offline channels. The inter-channel support in crypto-tokens directs additional demand to the offline channel for effective coordination and mitigates channel competition. Furthermore, we study the impact of factors driving different levels of inter-channel competition on supply chain profits to investigate the effectiveness of the coordination mechanism.

The findings of this study deliver critical insights into the market dynamics under O2O competition. Additionally, they are of practical significance in enhancing coordination among competing channels. These insights contribute to literature and practice alike.

The rest of the study is organized as follows. Section 2 reviews relevant literature, and Section 3 introduces the crypto-coordination model based on game theory. Section 4 analyzes the model, and Section 5 discusses the study and its implications. Finally, Section 6 gives the concluding remarks.

## 2. LITERATURE REVIEW

Levi Strauss & Co.'s decision to abandon its direct sales channel to customers and the difficulties Home Depot faced while introducing its dedicated service channels are examples of problems arising from channel competition. The manufacturer's decision to engage in O2O distribution creates competition and conflicts among the competing channels.

Over the past two decades, research on effective coordination mechanisms has been rising to mitigate channel conflicts arising from competition. One set of literature discusses the role of coordination mechanisms in driving operational and channel decisions in supply chains (Ha et al., 2022, Zhou et al., 2023). In contrast, studies such as (Abhishek et al., 2016) and (Liu et al., 2021) examine the competition intensity in such competing channels and its influence on quality of service across available channels. Very different from these studies, one stream of literature explores hybrid channel delivery. Put another way, an upstream entity offers various modes to different downstream partners (Tian et al., 2018, Zenny, 2020). Lu et al. (2023) and Ha et al. (2022) found that information sharing can be introduced among participants to elevate the intensity of competition and improve their cooperation.

Closer to our study, (Tsay and Agrawal, 2004) used sales efforts to coordinate between two supply chain players selling identical products. Here, they did not consider price as a decision variable. Addressing the gap, (Cattani et al., 2006) developed an equal pricing strategy to address channel conflicts. Unlike these studies, (Amrouche and Yan, 2016) illustrated the use of quantity discounts and whole-channel prices to promote coordination among the manufacturer, traditional retailers, and a new online retailer. Furthermore, studies such as (Choi et al., 2020) and (Zhang et al., 2019) study the price contract in coordination, such as revenue sharing and fixed fees, for their optimality in scenarios that span from fashion products and groceries to on-demand services. More recently, (Yan et al., 2019) proposed using reward points and profit sharing to facilitate coordination. However, similar to most of the studies above, they did not

discuss the lack of transparency in the supply chain and the lack of trust in the coordination mechanism that arises.

The past studies have not considered the need for transparency to motivate the adoption of coordination mechanisms in supply chains. Even though blockchain technology is promising to deliver transparency in the supply chain (Niu et al., 2024, Wu et al., 2023), previous papers did not consider coordination enabled via a blockchain network and did not explore the application of blockchain native incentive mechanism-crypto-tokens. Hence, in this study, we leverage crypto-tokens as the medium to extend inter-stakeholder support required to coordinate the supply chain under channel competition.

Table 1. Notations and definitions

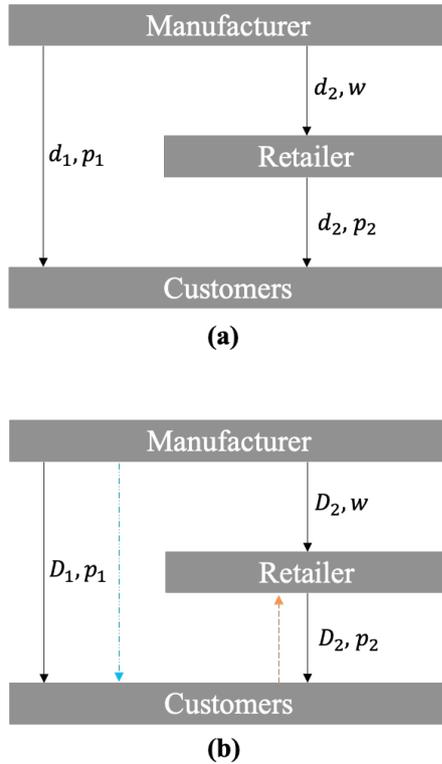
Notation	Definition
$u$	Consumption value for buying products offline
$\gamma u$	Consumption value for buying products online
$u^p$	Marginal customer's value for online channel
$u^b$	Marginal customer's value for offline channel
$u^{pb}$	Marginal customer's value for buying offline or online
$\gamma$	Channel synergy
$p_1$	Product price when buying online
$p_2$	Product price when buying offline
$w$	The product's wholesale price
$v$	Crypto-tokens reward
$m$	Impact of crypto-tokens on offline channel demand
$n$	Cost of crypto-tokens
$S_0$ and $S_1$	Manufacturer's profit with benchmark and crypto-coordination model
$L_0$ and $L_1$	Retailer's profit with benchmark model and crypto-coordination model

## 3. CRYPTO-COORDINATION MECHANISM

The blockchain for coordinating competing channels caters to transparency and traceability of transactions (e.g., product sales) in online and offline channels in the supply chain. It facilitates sharing and using information, which holds information relating to the sale in individual channels. Therefore, stakeholders of the supply chain track and trace the information required to build trust and facilitate the adoption of a coordination mechanism.

Despite adopting blockchain to enhance transparency, the competing channels within the supply chain create channel conflicts and competition from the demand cannibalization concerns from supply chain stakeholders. For example, consider a scenario where the book manufacturer uses a digital platform to sell its products directly to customers. As more customers buy online, fewer customers visit the offline stores of retailers to purchase these books. The manufacturer gains a competitive advantage in the market as it cannibalizes the demand experienced by the retailer. Therefore, the retailer hesitates to manufacture and introduce a competing online channel that threatens demand cannibalization. As a result, the need for an effective coordination mechanism becomes inevitable to support stakeholder participation in the blockchain network to coordinate O2O distribution.

Consider a supply chain with two competing channels: an *offline* channel of the manufacturer and retailer interacting through a blockchain network and an *online* channel of the manufacturer selling directly to customers through a digital platform. The manufacturer can deliver its products to customers through its online or offline channel using a Stackelberg game, as shown in Figure 1 (a). Table 1 gives the notations that appear in the models.



→ Channels    - - - - - Tokens reward    - - - - - Token redemption

Figure 1. Competing channels in the supply chain with (a) no coordination, and (b) crypto-coordination

Here, the synergy or compatibility of e-commerce products to different channels determines the demand for individual channels. We assume that customers who buy from online channels experience less consumption value than those who acquire an identical product from an offline retailer. The offline retailers provide features, such as transparent product features, flexible return policies, and convenient post-purchase services, that can serve a wide variety of customer requests. For instance, for a product like a trouser, features such as fit are more transparent when visiting an offline store and gives instant gratification on purchase. Uncertainty still looms even if the consumer evaluates features from an offline store before ordering the same product online. Similarly, consumers who wish for efficient post-purchase services opt for offline retail channels as online sellers tend to be distributed across diverse locations, making convenient/immediate services difficult. Therefore, the customer experiences a lower consumption value of the product from the online channel compared to the offline channel run by the retailer. We use the synergy factor  $\gamma$ , where  $0 < \gamma < 1$ , to represent the decrease in consumption value—a decrease in value of  $\gamma$  decreases the

synergy between the product and the online digital platform of the manufacturer.

Note that few products, such as concert tickets, books, etc., experience particular advantages to be sold through an online platform, i.e.,  $\gamma > 1$ . However, we dedicate this aspect to future research.

Table 2. Equilibrium solutions of the benchmark model

Product Wholesale price, $w$	$\gamma/2$
Online Channel price, $p_1$	$\gamma/2$
Offline price, $p_2$	$1/2$
Manufacturer's profit, $S_0$	$\gamma/4$

3.1 Benchmark model with no coordination

Let the price of products purchased through online and offline channels be  $p_1$  and  $p_2$ , respectively. Customer who opts for services from the online channel experiences a consumption value  $\gamma u$ , where smaller values of  $\gamma$  capture decreasing consumption value from the online channel. The customer surplus can become  $\gamma u - p_1$ . Conversely,  $u - p_2$  stands for the customer surplus generated from the offline channel. We assume  $u$  to be uniformly distributed, with uniform density, between 0 and 1, where  $u$  is the consumption value of the customer.

Therefore, customer channel selection depends on whether they receive a positive surplus. The customers select the online channel for when they experience a positive surplus, i.e.,  $\gamma u - p_1 \geq 0$ . On the other hand, marginal customers, with a consumption value  $u^f = p_1/\gamma$ , stays indifferent to the online channel. Similarly,  $u - p_2 \geq 0$  drives the customers to select the offline channel, whereas the customers with  $u^n = p_2$  stays indifferent to the retailer.

When the online and offline channels co-exist in the same supply chain, customers compare the surplus from individual channels for channel selection. Therefore,  $u - p_2 \geq \gamma u - p_1$  leads to the selection of offline channels and vice versa. Furthermore, marginal customers whose consumption value is  $u^{fn} = (p_2 - p_1)/(1 - \gamma)$ , stay indifferent to either channel.

If  $d_1$  and  $d_2$  are the demands for online and offline channels, respectively, then:

$$d_1 = \frac{p_2 - p_1}{1 - \gamma} - \frac{p_1}{\gamma} \tag{1}$$

$$d_2 = 1 - \frac{p_2 - p_1}{1 - \gamma} \tag{2}$$

The profit function of the manufacturer who serves products through both offline and online channels is given by:

$$S_0 = p_1 d_1 + w d_2 \tag{3}$$

The retailer's profit function is given by:

$$L_0 = (p_2 - w) d_2 \tag{4}$$

In the Stackelberg game, First, the manufacturer decides the profit-maximizing values of  $p_1$  and  $w$ . The retailer responds by selecting  $p_2$  that maximizes its payoff. Table 2 gives the corresponding optimal solutions.

### 3.2 Model for crypto-coordination mechanism

Figure 1 (b) illustrates the crypto-coordination we introduce to coordinate the competing channels in e-commerce. The sales information is recorded in the shared ledger of the blockchain through a smart contract. The smart contract works so that the purchase of a product by the customer from the digital platform (or directly from the manufacturer) triggers the creation of non-fungible crypto-tokens with a fixed value (Harish et al., 2023a, Harish et al., 2023b). The tokens represent the customer’s immutable purchase history from the digital platform. The customer’s purchase triggers a flow of tokens from the smart contract to the customer’s wallet. The higher the number of times the customer purchases the product from the digital platform, the higher the number of tokens he receives. Therefore, the blockchain network keeps tabs on who bought the product or how many products were bought (sales information) and delivers the rewards as tokens.

Suppose a customer receives  $v$  tokens. These tokens act as a value indicator for redeeming products from the offline channel (or retailer). Providing such purchase-based benefits is common in the airline industry, where travelers are rewarded with redeemable air miles when opting for specific airlines. In an e-commerce setting, the tokens help the customers buy more products from the retailer, directing a portion of online demand to the offline channel. As a result, an increase in token collection translates to increased demand for offline channels (or retailers).

On the other hand, the manufacturer’s online channel experiences a decrease in demand from providing symbolic benefits in tokens to the customers. Furthermore, the channel synergy of products affects the impact of tokens on the demands of offline and online channels. At higher product synergy to an online channel, the manufacturer’s product sales through the digital platform directly conflict with the retailer’s offline operations. Therefore, a more significant portion of demand moves with token rewards from online to offline. If  $D_1$  and  $D_2$  represent the demands of online and offline channels, respectively, we have:

$$D_1 = d_1 - (1 - \gamma)mv = \frac{p_2 - p_1}{1 - \gamma} - \frac{p_1}{\gamma} - (1 - \gamma)mv \quad (5)$$

$$D_2 = d_2 + mv = 1 - \frac{p_2 - p_1}{1 - \gamma} + mv \quad (6)$$

where,  $m$  ( $0 < m < 1$ ) represents the token’s impact on the offline channel demand. A large value of  $m$  indicates a higher significance of tokens in enhancing customer engagement in offline channels. Notably, the manufacturer experiences the cost of providing tokens to customers when they purchase products from retailers using redeemed tokens. Therefore, the total number of customers who redeem their token at the retailer is modeled as  $q = nv$  where,  $n$  is the rate of redemption concerning  $v$ . The associated cost to the manufacturer becomes:

$$c = nv^2 \quad (7)$$

where, the value of the cost factor  $n$  lies in the interval  $(0, m)$  as all the customers redeeming their tokens is uncommon. Therefore, the profit of the manufacturer and the retailer becomes:

$$S_1 = w \left( 1 - \frac{p_2 - p_1}{1 - \gamma} + mv \right) + p_1 \left( \frac{p_2 - p_1}{1 - \gamma} - \frac{p_1}{\gamma} - (1 - \gamma)mv \right) - nv^2 \quad (8)$$

$$L_1 = (p_2 - w) \left( 1 - \frac{p_2 - p_1}{1 - \gamma} + mv \right) \quad (9)$$

In the Stackelberg game, first, the manufacturer determines the optimal values of  $p_1$ ,  $w$ , and  $v$  that maximize its payoff. The retailer sets its selling price,  $p_2$ , in response to maximize its profit. Table 3 gives the corresponding optimal solutions.

Product’s Wholesale price, $w$	$2n\gamma/(4n - \gamma^3 m^2)$
Online price, $p_1$	$2n\gamma/(4n - \gamma^3 m^2)$
Offline price, $p_2$	$(4n + (1 - \gamma)^2 \gamma^2 m^2) / (8n - 2\gamma^3 m^2)$
Crypto-tokens, $v$	$(\gamma^2 m) / (4n - \gamma^3 m^2)$
Manufacturer’s profit, $S_1$	$(n(4n\gamma + (1 - 2\gamma)\gamma^3 m^2)) / (4n - \gamma^3 m^2)^2$
Retailer’s profit, $L_1$	$((1 - \gamma)(4n + (1 - \gamma)\gamma^2 m^2)^2) / (4(4n - \gamma^3 m^2)^2)$
where, $4n - \gamma^3 m^2 > 0$	

## 4. ANALYSIS OF CRYPTO-COORDINATION MECHANISM

For a crypto-coordination mechanism introduced to promote coordination, we first examine the impact of the channel synergy factor,  $\gamma$ , on the tokens rewarded in Proposition 1.

*Proposition 1:* While a crypto-coordination mechanism is put in place to promote coordination of competing channels, the increase in channel synergy factor,  $\gamma$ , leads to an increase in crypto-tokens,  $v^*$ .

Taking the first derivative of the optimal value of  $v$ , from Table 3, with respect to  $\gamma$  produces a positive value, i.e., crypto-token reward increases with the channel synergy factor.

When  $v^* = \frac{\gamma^2 m}{4n - \gamma^3 m^2}$ , the expression for  $\frac{\partial v}{\partial \gamma}$  is given by  $\frac{\partial v}{\partial \gamma} = \frac{8n\gamma m + \gamma^4 m^3}{(4n - \gamma^3 m^2)^2} > 0$ . The competing channels become more substitutable with increased product synergy with the manufacturer’s online platform. Therefore, purchasing a product directly from a manufacturer intensifies competition between sales channels. Thus, the manufacturer provides more tokens to customers to mitigate the resulting channel conflicts. The increase in the number of tokens, in turn, increases the demand in the offline channel.

Now, to demonstrate the Pareto improvement (competitive advantage) brought by the crypto-coordination strategy over the benchmark model, we compare the profits of the manufacturer and retailer from Table 3 with Table 2 to produce proposition 2. The profits of the manufacturer and the retailer under the token-coordination mechanism are  $S_1 = \frac{n(4n\gamma + (1 - 2\gamma)\gamma^3 m^2)}{(4n - \gamma^3 m^2)^2}$  and  $L_1 = \frac{(1 - \gamma)(4n + (1 - \gamma)\gamma^2 m^2)^2}{4(4n - \gamma^3 m^2)^2}$ , respectively. Hence,  $\frac{\partial S_1}{\partial \gamma} = \frac{n(16n^2 + 12n(1 - \gamma)\gamma^2 m^2 + (3 - 4\gamma)\gamma^5 m^4)}{(4n - \gamma^3 m^2)^2} > 0$ ; similarly we can

obtain  $\frac{\partial L_1}{\partial \gamma} < 0$ . The profits under the benchmark model are  $S_0 = \frac{\gamma}{4}$  and  $L_0 = \frac{1-\gamma}{4}$ , respectively. By comparing  $S_1$  with  $S_0$ , it is clear that  $S_1 - S_0 = \frac{\gamma^3 m^2 (4n - \gamma^4 m^2)}{4(4n - \gamma^3 m^2)^2} > 0$ . Similarly, we can show that  $L_1 - L_0 > 0$ , thereby supporting Proposition 2.

**Proposition 2:** When a crypto-coordination mechanism is introduced into the supply chain to promote coordination, both manufacturer and retailer profit from the reduction in conflict.

Proposition 2 shows that introducing a crypto-coordination mechanism benefits the retailer. The token reward from the manufacturer to the retailer elevates the demand for the offline channel, increasing the retailer's profits. Similarly, a higher level of product synergy in the online channel attracts more customers to the dedicated online platform from the manufacturer. Therefore, the manufacturer provides more tokens for online purchases to compensate, leading to increased profits for the retailer, as shown in Fig 3 (a).

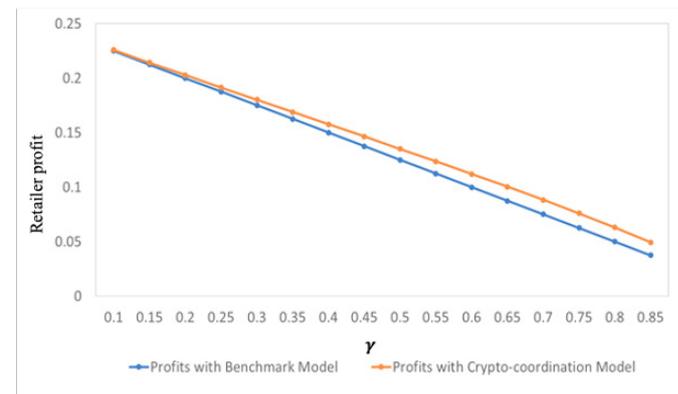
On the other hand, rewarding tokens to customers risk losing the demand for the manufacturer's dedicated online channel. However, the benefits from an increase in demand for the offline channel exceed the losses from the corresponding decrease in the online channel. Therefore, the manufacturer also benefits from introducing a crypto-coordination mechanism to promote supply chain coordination. Notably, an increase in channel synergy increases the benefits of the manufacturer, as shown in Fig 3 (b). Therefore, compared to the benchmark model, the performance of the retailer and manufacturer is seen to increase with the channel synergy of products to the dedicated online channel of the manufacturer, displaying the coordination power of the mechanism.

## 5. DISCUSSION AND IMPLICATIONS

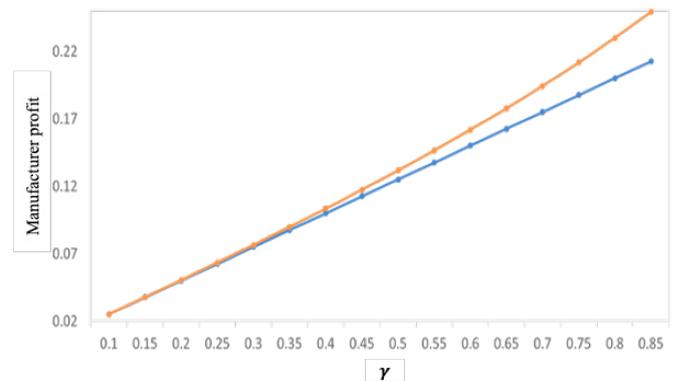
The growth in e-commerce and the rise in popularity of digital platforms over the past decade has seen manufacturers increasingly attempting to introduce channels to directly sell to customers online, leading to conflict and competition with traditional retailers concerned about the decline in their offline product sales. Unlike existing literature, this study proposes a novel crypto-coordination mechanism to alleviate channel conflicts and improve coordination in manufacturer–retailer supply chains with competing channels. Specifically, this study first investigated a few valuable game theoretical models to show the strategic advantages of the crypto-coordination mechanism. We find that the crypto-coordination mechanism based on token reward is critical to formulating optimal coordination policies in supply chains. When the product is less compatible with the online channel, we observe that it is in the manufacturer's best interest to introduce a crypto-coordination mechanism. The proposed coordination mechanism benefits the supply chain by enhancing channel coordination and producing increased profits for all participants. As a result, despite the manufacturer bearing the disutility from delivering financial support in crypto-tokens to the retailer, the novel mechanism remains valuable in alleviating conflict and enhancing the performance of all stakeholders in O2O distribution.

Additionally, the manufacturer should consider the product's compatibility with individual channels before introducing an

online channel and the coordination mechanism. This factor is critical to investment and the outcomes generated thereof. To summarize, if implemented correctly, the novel crypto-coordination mechanism offers managerial insights to support smart investments aimed at enhancing profits.



(a) Retailer profits



(b) Manufacturer profits

Note: All figures use parameter values  $m = 0.7, n = 0.6$

Figure 2. The effect of channel synergy of product on sales

## 6. CONCLUSIONS

This paper introduced a crypto-coordination mechanism to facilitate the coordination of an e-commerce supply chain. The mechanism used tokens to address the channel conflicts that arise from manufacturers competing with traditional retailers through its dedicated online platform for product sales. We showed that the crypto-coordination mechanism stimulates Pareto performance of the supply chain.

This study makes two significant contributions to the existing literature. First, it advances the literature and understanding of blockchain applications in O2O coordination. Second, it contributes a novel crypto-coordination mechanism to support stakeholder participation. The mechanism mitigates channel conflicts for sustainable O2O distribution when the manufacturer joins a digital platform to sell e-commerce products directly to customers. The game theoretical model considers various factors, such as the cost of tokens and channel synergy, to evaluate their impact on the supply chain.

Future research may extend this study in the following directions. Firstly, the crypto-coordination mechanism could be compared against the existing coordination mechanisms,

such as profit sharing and a hybrid mechanism that combines profit sharing and token rewards. Secondly, studies should aim to validate the theoretical implications of this study through empirical examination. Finally, the mechanism in this study can be further enhanced by considering various modes of conduct or decision sequences in supply chains, such as leader-follower, simultaneous decision, etc., to evaluate its effectiveness in practical supply chain applications.

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