

Dual-channel Strategy Selection in Multinational Supply Chain in E-Commerce

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Abstract. With the globalization of the economy and the rise of e-commerce, cross-border transactions have become increasingly prevalent, enabling consumers to access high-quality products from brands worldwide, and brands to open new market overseas. In order to examine the overseas market development strategy of domestic manufacturers on the basis of traditional retail, this paper applies game theory to establish two dual-channel models including a domestic manufacturer and an e-retailing platform, and analyzes the channel selection of the manufacturer based on analytical deduction as well as numerical calculations. According to the analysis, though the introduction of dual-channel can alleviate the double marginalization in the multinational supply chain, the Nash equilibrium only exists in the scenario where the domestic manufacturer chooses the agency sales channel, due to the profit compensation of commission. Overall, these results shed light on the operation of multinational supply chain and bring some valuable insights on overseas market development in the era of e-commerce.

Keywords: dual-channel; multinational supply chain; transnational operation; e-commerce; game theory.

1. Introduction

With the impact of economic globalization, production and consumption have gradually expanded from the national scope to the global scope, so that consumers can obtain high-quality products produced by brands in other countries. At the same time, with the rise of e-commerce, the status of e-commerce platforms in cross-border transactions continues to improve [1]. Take China as an example, overall e-commerce transactions of China have exceeded 43.83 trillion yuan in 2022 [2]. Chinese consumers buy cosmetics and health care products, CDs, and electronic devices from international markets (such as the United States, Japan, Australia). through e-commerce platforms. At the same time, China is also exporting mobile phones and accessories, fashion, health and beauty, and sports and outdoor goods to the United States, the United Kingdom, Japan and South Korea. E-commerce platforms build bridges between consumers and brands in different countries and provide consumers with direct access to cross-border goods.

On the other hand, from the perspective of brands or manufacturers, it is common to sell products to consumers in other countries through e-commerce platforms, although in most cases there are different versions of the same product series in different countries due to the influence of policy regulations, raw material supply, etc. At the same time, in order to further expand overseas markets, many brands are trying to operate offline physical store or online store to gain benefits from tax policies or platform incentives [3].

In order to study the channel strategy of a domestic manufacturer who wants to further expand overseas markets on the basis of cross-border e-commerce and multinational supply chain, a dual-channel multinational supply chain game-theoretical model between a domestic manufacturer and an e-retailing platform is established and several significant insights are obtained. It is finally found that although the both dual-channel strategies can mitigate the double marginalization, only the online store by agency channel can both benefit the manufacturer and the platform due to the compensation of commission, which could be the only one Nash equilibrium in the game.

This research proceeds as follows. Section 2 shows the relative literature, and describes contributions. Section 3 describes the model settings, basic parameters and equilibrium outcomes. Section 4 presents the core analysis and findings. Section 5 provides conclusion and future outlooks.

2. Literature Review

This research is related to studies on dual-channel supply chain and supply chain encroachment. Earlier research by Chiang et al. has shown that the supplier encroachment can improve the retail channel by preventing higher prices, which overturns the common wisdom that dual-channel damages the retailer [4]. Latter studies have focused on the impact of dual-channel on manufacturer and retailer. Arya et al. further proved the advantages of supplier encroachment on mitigating double marginalization, which benefits channel members [5]. Matsui detailed when should a manufacturer announce its pricing decision [6]. In recent years, with the development of e-commerce, more researchers have shifted their eyes to the study of dual-channel strategy with an online channel. Abhishek et al. studied the channel selection of agency selling and reselling under the electronic retailing scenario to identify when should agency selling be used and the implication of using it [7]. Shi et al. studied the impact of supplier encroachment with an independent e-commerce division [8]. Wu et al. studied the encroachment scenario with an e-platform but not an offline retailer [9].

This research contributes to this field by considering a manufacturer's dual-channel selection problem under an international transaction perspective, and further applies the result of Matsui's research [6] to study a domestic manufacturer's decision when setting its wholesale price and direct sales price at the same time.

Thus, this research is also related to studies on multinational supply chain and overseas operation. Shi et al. have examined that a domestic brand opens its overseas market when the encroaching channels are beneficial under the impact of purchasing agency, but it will stick to the domestic market when there is huge uncertainty for overseas consumers to buy a product from agents [10]. Niu et al. studied a cross-border e-platform facing the quality verification from the MNF's blockchain decision, which have shown that the taxation and downstream competition can affect MNF's decision on participating the blockchain [11]. Dong et al. studied the impact of tariff on global supply chain under different competition scenarios [12]. This research contributes to the literature in this field by considering the import tariff collection nodes and different pricing strategy of the domestic manufacturer and the e-retailing platform under the impact of import tariff, which expand the research of global operation.

3. Model Settings

A multinational supply chain scenario is considered in this research, where a domestic manufacturer (denoted as M) selling its product to overseas consumers in other countries through an overseas e-retailing platform (denoted as R) by the wholesale contract (Strategy R). Brands such as Shiseido and Nike selling their products to consumers in other countries through JD.com, Amazon and other platforms is a typical example. Now, the domestic manufacturer wants to open a new channel to improve its overseas sales while retaining the original sales channel. Depending on the mode of operation and the channel choice, two dual-channel strategies are studied and channel structures are shown in Fig. 1.

For Strategy RA, by signing the agency contract with the e-retailing platform, the manufacturer opens its own online store on the platform and sells product through the platform. In this scenario, since the platform is fully responsible for the sales process, it is assumed that the manufacturer will not incur additional costs. However, the manufacturer needs to pay a commission to the platform in proportion to the actual transaction amount. The commission rate is represented by $\alpha \in (0,1)$. Furthermore, the commission rate of e-retail platforms is generally low today, such as 5% of sales for Shopee, 1%-4% for Lazada, 1%-3% for JD and T-Mall, and 15% for Wish, which is the highest. Thus,

without the loss of generality, α is further limited to $(0, 1/5)$, which is a more realistic setting. For Strategy RO, the manufacturer builds new distribution channel by opening an overseas offline direct sales store. In this scenario, since the manufacturer is fully responsible for the direct sales and the operation of the direct store, it is assumed that the manufacturer bears a unit direct sales cost $c > 0$.

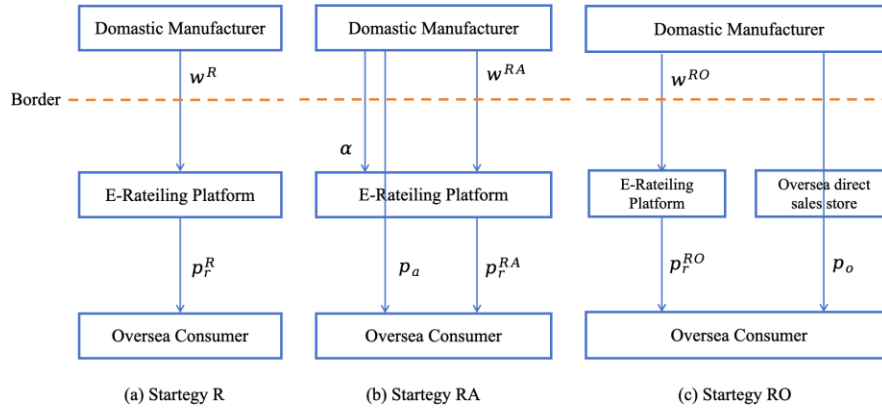


Fig. 1 Channel structures.

Another important factor affecting the sales of products in the multinational supply chain is import tariffs. The imposition of import tariffs will increase the cost and market price of imported goods, thus affecting the quantity of foreign goods imported and sold. The imposition of import tariffs usually occurs after the first transfer of ownership of goods after entering the market of another country, and is levied on the new owner at a certain ratio of the value of the product. Here, assume that the ratio (i.e., the tariff rate) is $t \in (0, 4/5)$ without the loss of generality after investigating the import tariff policies of major countries in the world. The notations used in this paper are summarized in Table 1.

Table 1. Notations

Notations	Meanings
p_r^j	The retailing price in the wholesale channel determined by the e-retailing platform, where $j \in \{R, RA, RO\}$
p_i	The sales price of the new channel determined by the domestic manufacturer, where $i \in \{a, o\}$
w^j	The wholesale price determined by the domestic manufacturer, where $j \in \{R, RA, RO\}$
t	The import tariff rate determined by the overseas government
α	The commission rate determined by the e-retailing platform
β	The cross-price sensitivity of the two channels
q_r^j	The quantity of the wholesale channel, where $j \in \{R, RA, RO\}$
q_i	The quantity of the new channel, where $i \in \{a, o\}$
π_M^j	The profit of the domestic manufacturer, where $j \in \{R, RA, RO\}$
π_R^j	The profit of the e-retailing platform, where $j \in \{R, RA, RO\}$
Subscript i	Channels
a	Agency sales channel
o	Overseas direct sales channel
Superscript	Strategies
R	Strategy R: wholesale channel only
RA	Strategy RA: wholesale channel + agency sales channel
RO	Strategy RO: wholesale channel + overseas direct sales channel

In Strategy R (benchmark), the demand function and the profit functions are:

$$q_r^R = 1 - p_r^R, \pi_R^R = q_r^R(p_r^R - (1+t)w^R), \pi_M^R = w^R q_r^R \quad (1)$$

In Strategy RO, the demand functions and the profit functions are:

$$q_r^{RO} = 1 - p_r^{RO} - \beta p_o, q_o = 1 - p_o - \beta p_r^{RO} \\ \pi_R^{RO} = q_r^{RO}(p_r^{RO} - (1+t)w^{RO}), \pi_M^{RO} = \left(\frac{p_o}{1+t} - c\right)q_o + w^{RO}q_r^{RO} \quad (2)$$

In Strategy RA, the demand functions and the profit functions are:

$$q_r^{RA} = 1 - p_r^{RA} - \beta p_a, q_a = 1 - p_a - \beta p_r^{RA} \\ \pi_R^{RA} = \alpha p_a q_a + q_r^{RA}(p_r^{RA} - (1+t)w^{RA}), \pi_M^{RA} = \left(\frac{1}{1+t} - \alpha\right)p_a q_a + w^{RA}q_r^{RA} \quad (3)$$

It is well noticed that the price settings of the domestic manufacturer are different. To be specific, when the wholesale price is set, the domestic manufacturer decides the **Price Before Tax**, but when setting the agent channel price/direct sales price, the manufacturer decides the **Tax-inclusive Price**, which is consistent with the realistic scenario of international commodity trading. When wholesaling goods, the domestic manufacturer will face distributors/retailers in different countries. Under this situation, the manufacturer won't consider the tariff of one country alone, but set a uniform pre-tax wholesale price. However, when moving to the agency/direct sales channel, what the manufacturer has to decide is the final price to be displayed in front of the consumer which generally including the import tariff. It has been proved that the manufacturer should post the direct price before but not after, setting the wholesale price for the retailer in the dual-channel scenario [6]. Thus, the sequence of the game is as follows: First, the domestic manufacturer decides its wholesale price and agency/direct channel price. Second, seeing that, the e-retailing platform sets its retail price. The sequence of game is also shown in Fig. 2.

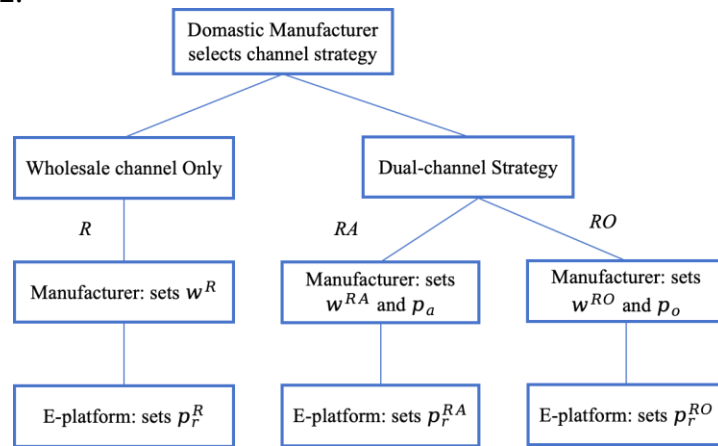


Fig. 2 The sequence of the game

Solving the problem by backward induction and equilibrium outcomes of three strategies can be obtained in Table 2.

Table 2. Equilibrium outcomes.

	Strategy R $j = R$	Strategy RO $j = RO, i = o$	Strategy RA $j = RA, i = a$
p_r^j	$\frac{3}{4}$	$\frac{3 + \beta - c(1+t)\beta(1+\beta)}{4(1+\beta)}$	$\frac{(t\alpha + \alpha - 1)(6 + \beta(t\alpha - 4)) - (\alpha(2 + t(8 - \alpha) + 1))}{8(t\alpha + \alpha - 1) + (8 + \alpha(t(t\alpha - 8) - 8))\beta}$
p_i	N/A	$\frac{1 + c(1+t)(1+\beta)}{2(1+\beta)}$	$\frac{\alpha(4 + t(4 - 3\beta) - 4\beta) + 4(\beta - 1)}{8(t\alpha + \alpha - 1) + (8 + \alpha(t(t\alpha - 8) - 8))\beta}$
w^j	$\frac{1}{2(1+t)}$	$\frac{1}{2(1+\beta)(1+t)}$	$\frac{(t\alpha + \alpha - 1)(4 - \beta(4 - 2(2+t)\alpha + 4)) - (\alpha(2 + t(8 - \alpha) + 1))}{(1+t)(8(t\alpha + \alpha - 1) + (8 + \alpha(t(t\alpha - 8) - 8))\beta)}$
π_{M^j}	$\frac{1}{8(1+t)}$	$\frac{3 - \beta - c(1+\beta)(1+t)(4 - 2\beta + c(1+\beta))}{8(1+\beta)(1+t)}$	$\frac{(t\alpha + \alpha - 1)(1 - \beta)(3 - 2(1+t)\alpha - \beta) + (\alpha(2 + t(8 - \alpha) + 1))}{(1+t)(8(t\alpha + \alpha - 1) + (8 + \alpha(t(t\alpha - 8) - 8))\beta)}$
π_{R^j}	$\frac{1}{16}$	$\frac{(c\beta(1+t) - 1)^2}{16}$	$\frac{\Lambda_1}{(8(t\alpha + \alpha - 1) + (8 + \alpha(t(t\alpha - 8) - 8))\beta)}$

* Λ_1 is available in Appendix

4. Results and Discussion

4.1. Domestic Manufacturer's Strategy Choice

First of all, basic limitations are studied to answer the question of when will the manufacturer choose dual-channel strategy.

Lemma 1: (i) Strategy RO is an available choice for the domestic manufacturer if and only if $0 < c < c_1$, where $c_1 = 1/(1+t)(1+\beta)$; (ii) Strategy RA is an available choice for the domestic manufacturer if and only if $0 < \alpha < \min \{\alpha_1, 1/5\}$, where $\alpha_1 = 4(\beta-1)/[\beta(3t+4)-4(t+1)]$.

The upper bound of unit direct sales cost and commission rate are aimed at making sure that there is a positive marginal profit for the manufacturer in strategy RO and RA.

4.2. Channel Member's Pricing Decision

Before the analysis of channel selection, this paper first examine how different channel strategy affects the pricing of the channel member based on the results of Lemma 1, and results are summarized in Lemma 2 and Lemma 3.

Lemma 2: After comparing the equilibrium prices in the same channel in different scenario, it is proved that when strategy RO and RA are both available: (i) $w^R > w^{RA} > w^{RO}$; (ii) $p_r^R > p_r^{RA} > p_r^{RO}$; (iii) $p_o > p_a$.

Lemma 2(i)(ii) reveals that the wholesale prices and retail prices in dual-channel strategy are lower than those of the single-channel scenario. When the domestic manufacturer opens its new sales channel, it will be competitive for the e-retailing platform. This action can also be seen as encroachment in many research now [5, 8, 9]. In this situation, the manufacturer is inclined to reduce its wholesale price as a compensate to the e-retailing platform when the platform reduces its retail price to maintain the demand. Thus, the double marginalization problem in the supply chain can be diminished, which is considered as a good result for the channel members and consumer.

Lemma 2(iii) indicates that when both dual-channel strategies are available choices, the agency channel price is always lower than overseas direct channel price. The intuition is, the domestic manufacturer has to bear the direct sales cost in strategy RO and the platform commission fee in strategy RA, but the unit direct sales cost is always higher than the commission rate (it is easy to prove that $c_1 > 1/5$ with all feasible t and β). Meanwhile, compared with the commission rate, which affects the profit in the form of proportional deduction, the unit direct sales cost will directly affect the unit sales revenue, which will amplify the negative impact of direct sales cost on final profit. Thus,

the manufacturer needs to increase its overseas direct sales price to ensure enough marginal profit when choosing strategy RO.

Lemma 3: After comparing the equilibrium prices across channels in the same scenario, it is proved that: (i) When strategy RO is available: $p_r^{RO} > p_o$ if $0 < c < c_2$, and $p_o > p_r^{RO}$ if $c_2 < c < c_1$, where $c_2 = 1/(1+t)(2+\beta)$; (ii) When strategy RA is available: $p_r^{RA} > p_a$ with all feasible α , t and β .

The results of Lemma 3 further verify the different effects of unit sales cost and commission rate from platform on domestic manufacturer. Meanwhile, in the scenario of multinational supply chain, the import tariff is unavoidable. It is well noting that the two thresholds of c are both decrease with t . When the import tariff rate increases, the e-retailing platform and consumers who buy the product from overseas direct channel bear more import tariff than before, which means the manufacturer should reduce its wholesale price to maintain the demand from the platform while gaining less from direct channel at the same time. In this situation, under the influence of the additional costs brought by a higher t , the unit direct sales cost condition for the establishment of strategy RO will be stringent. At this time, the domestic manufacturer will be more inclined to raise its direct sales price when c is high. (it is easy to prove that $\partial c_1/\partial t < \partial c_2/\partial t < 0$).

4.3. Domestic Manufacturer's Dual-Channel Strategy

Based on the equilibrium outcomes and price analysis, the manufacturer's best dual-channel strategy can be investigated. The main analysis of this section is aimed at figuring out how the manufacturer should make its strategy selection between strategy R, RA and RO. Based on equilibrium outcomes and the analysis before, the strategy RO and RA are studied and results are summarized in Proposition 1 and Proposition 2.

Proposition 1: (i) When strategy RO is an available choice, the domestic manufacturer can benefit from strategy RO (i.e. $\pi_M^{RO} - \pi_M^R > 0$) if and only if $0 < c < c_3$, where c_3 is available in Appendix; (ii) When strategy RA is an available choice, the domestic manufacturer can benefit from strategy RA (i.e. $\pi_M^{RA} - \pi_M^R > 0$) if and only if $0 < \alpha < \min \{\alpha_1, 1/5\}$.

The results in Proposition 1(i) shows that, compared with strategy R, the strategy RO is profitable only when c is relatively low. To be specific, when c is low (i.e. $0 < c < c_3$), the marginal profit in the overseas direct sales channel can cover the loss caused by the price reduction of wholesale price while the marginal profit is too small to benefit the manufacturer when c is high (i.e. $c_3 < c < c_1$). Meanwhile, $\partial c_3/\partial t < 0$ indicates that the existence of import tariff makes it harder for strategy RO to be profitable, which is consistent with previous analysis.

Lemma 1(ii) and Proposition 1(ii) indicate that the domestic manufacturer will always choose strategy RA as long as strategy RA is available rather than strategy R. Furthermore, $\partial \alpha_1/\partial t < 0$ indicates that the manufacturer's profitability is negatively correlated with the import tariff rate as well. The results from proposition 1 reveals that high commission rate should be avoided. One might think that the domestic manufacturer will increase the agency sales price when α increases to ensure its profit on agency channel. However, it is surprising that in strategy RA, $\partial p_a/\partial \alpha < 0$ while $\partial p_r^{RA}/\partial \alpha > 0$ and $\partial w^{RA}/\partial \alpha > 0$. The intuition of these results is: when the platform increases its commission rate, the domestic manufacturer increases its wholesale price and decreases its agency sales price as a way of protecting its profit from the wholesale channel and competing with the platform by using its agency channel with a lower price, which is seen as a countering response towards the price increasing from the e-retailing platform and exacerbates the double marginalization in the multilevel supply chain, which harms the channel member. On the other hand, the import tariff makes the channel member less profitable by lowering their income as long as wholesale (the platform) or direct sale (the manufacturer) happens, which can make the strategy RA harder to achieve.

Proposition 2: When both dual-channel strategies are profitable compared with strategy R, the domestic manufacturer prefers RA rather than RO (i.e. $\pi_M^{RA} > \pi_M^{RO}$) if and only if $c_4 < c < c_3$; the domestic manufacturer prefers RO rather than RA (i.e. $\pi_M^{RO} > \pi_M^{RA}$) if and only if $0 < c < c_4$, where c_4 is a function of α and is available in Appendix.

Proposition 2 reveals the important role of the relationship between direct sales cost and commission rate in channel selection. Given the commission rate from the platform, when the direct sales cost is high, the manufacturer will be less profitable in overseas direct channel and is more inclined to choose agency sales channel. Meanwhile, it is well noticed that $\partial c_4/\partial \alpha > 0$, which also indicates that given the direct sales cost in overseas direct sales channel, when there is a higher commission rate, it is more likely for the domestic manufacturer to benefit from dual-channel strategy when choosing strategy RO.

As for the impact of import tariff, it is proved that $\partial c_4/\partial t > 0$, which surprisingly means a higher import tariff rate is helpful when the domestic manufacturer chooses strategy RO. The manufacturer decreases wholesale price but increases direct sales price, and the platform decreases retail price when t is higher under the strategy RO (i.e. $\partial w^{RO}/\partial t < 0$, $\partial p_r^{RO}/\partial t < 0$ and $\partial p_o/\partial t > 0$), which diminishes the double marginalization and causes increase on the demand in the wholesale channel and covers the loss in the overseas direct sales channel, benefiting the manufacturer. Therefore, in this research, since direct sales cost, commission rate and import tariff rate are all exogenous variables, for domestic manufacturers, the selection of dual-channel strategy depends on specific parameter values in its operation. Fig. 3 shows the results of proposition 2 with $\beta = 5/6$ and $t = 0.25, 0.5$ or 0.75 , which corroborates the analysis above. It reveals that the area for strategy RA to be profitable becomes smaller but the area for strategy RO to be profitable becomes larger when t and α increase.

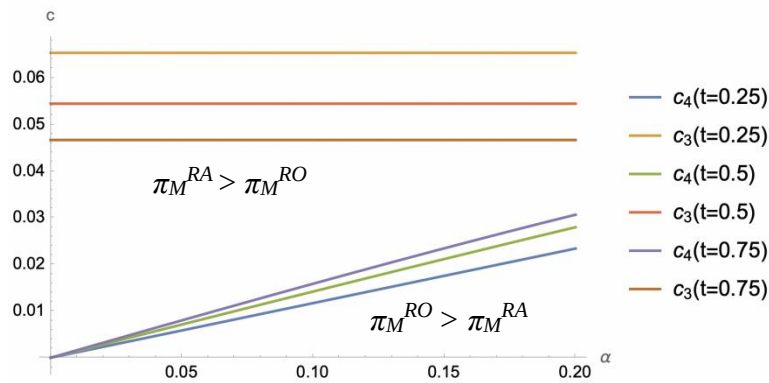


Fig. 3 Numerical study of Proposition 2.

4.4. The Impact on the E-retailing Platform

On the basis of the dual-channel strategy adopted by the domestic manufacturer, now this research explores the implications from the perspective of the e-retailing platform to examine how the dual channel strategy affects the platform.

Proposition 3: (i) The strategy RO will always harm the e-retailing platform (i.e. $\pi_R^{RO} - \pi_R^R < 0$ with all feasible parameter value); (ii) The e-retailing platform can benefit from strategy RA (i.e. $\pi_R^{RA} - \pi_R^R > 0$) if and only if $\max\{\alpha_2, 0\} < \alpha < \min\{\alpha_1, 1/5\}$, where α_2 is available in Appendix.

The intuition of proposition 3 is: when the domestic manufacturer chooses strategy RO, the wholesale price and retail price in the wholesale channel both decrease (proved in Lemma 2). However, it is also easy to prove that $\partial(w^R - w^{RO})/\partial t < 0$ but $\partial(p_r^R - p_r^{RO})/\partial t > 0$, which means the gap of wholesale prices becomes smaller but that of retail prices become larger as t increases. At the same time, the wholesale price of strategy RO is not affected by c while the gap of retail price increase with c (i.e. $\partial(p_r^R - p_r^{RO})/\partial c > 0$). Under this situation, with the existence of import tariff and direct sales cost, the domestic manufacturer can squeeze more profit from e-retailing platform's price reduction and the demand increase in the wholesale channel, which benefits the manufacturer but harms the platform. From this perspective, the results of proposition 3 also supports and findings of proposition 2.

The proposition 2 and 3 finally indicate that the Nash equilibrium only exists when the domestic manufacturer chooses strategy RA with a higher direct sales cost (i.e. $c_4 < c < c_3$) and a moderate commission rate (i.e. $\max\{\alpha_2, 0\} < \alpha < \min\{\alpha_1, 1/5\}$). The profit compensation mechanism brought

by the commission rate effectively improves the opportunity for the platform to benefit in strategic RA.

5. Conclusion

To sum up, this research explored the dual-channel strategy selection of a domestic manufacturer selling its products through an overseas e-retailing platform. Strategy RA involved an agency contract with the platform, while Strategy RO entailed opening overseas offline direct stores. Findings indicate that although the manufacturer's choice depends on the commission rate, direct sales cost and the import tariff rate, the Nash equilibrium exists only when strategy RA is applied. However, this study has limitations, neglecting roles of other supply chain members and considering only the manufacturer as the leader. Future research could explore the impact of third-party sellers, VAT, tax disparity between countries and scenarios where the platform leads the game. This study offers valuable insights into optimizing cross-border sales channels but requires further exploration to capture the complexity of real-world multinational supply chains in cross-border e-commerce.

References

- [1] Statista, 2019. B2C E-Commerce Sales Worldwide from 2012 to 2018. Retrieved from: <https://www.statista.com/statistics/261245/b2c-e-commerce-sales-worldwide/>.
- [2] Statista, 2024. GMV of China's e-commerce market from 2012 to 2022. Retrieved from: <https://www.statista.com/statistics/1129543/china-e-commerce-market-gross-merchandise-volume/>
- [3] Arya A, Mittendorf B. Bricks-and-mortar entry by online retailers in the presence of consumer sales taxes. *Management Science*, 2018, 64(11): 5220–5233.
- [4] Chiang W K, Chhajed D, Hess J D. Direct Marketing, Indirect Profits: A Strategic Analysis of Dual-Channel Supply-Chain Design. *Management Science*, 2003, 49(1): 1–20.
- [5] Arya A, Mittendorf B, Sappington D E M. The Bright Side of Supplier Encroachment. *Marketing Science*, 2007, 26(5): 651–659.
- [6] Matsui K. When should a manufacturer set its direct price and wholesale price in dual-channel supply chains?. *European Journal of Operational Research*, 2017, 258(2): 501–511.
- [7] Abhishek V, Jerath K, Zhang Z J. Agency Selling or Reselling? Channel Structures in Electronic Retailing. *Management Science*, 2016, 62(8): 2259–2280.
- [8] Shi S, Wang C, Cheng T C E, Liu S. Manufacturer encroachment with an e-commerce division. *Production and Operations Management*, 2023: poms.13955.
- [9] Wu J, Bi G, Xu Y, Dang X. Channel structure of E-platform encroachment. *RAIRO - Operations Research*, 2023, 57(1): 157–181.
- [10] Shi X, Tang J, Dong C. Should a domestic firm carve out a niche in overseas markets? value of purchasing agents. *European Journal of Operational Research*, 2022, 300(1): 85–94.
- [11] Niu B, Mu Z, Cao B, Gao J. Should multinational firms implement blockchain to provide quality verification. *Transportation Research Part E: Logistics and Transportation Review*, 2021, 145: 102121.
- [12] Dong L, Kouvelis P. Impact of tariffs on global supply chain network configuration: Models, predictions, and future research. *Manufacturing & Service Operations Management*, 2020, 22(1): 25–35.

Appendix

$$\begin{aligned} \Lambda_1 = & t^2 \alpha^4 (-1 + \beta) \beta^2 (-t(6 + t) + 5(-1 + \beta) + t(5 + t)\beta) + 4(-1 + \beta^2)^2 + \\ & \alpha^2 (-1 + \beta)^2 (4(-7 + t)(1 + t) + 8(1 + t)(1 + 2t)\beta + (36 + t(48 + 13t))\beta^2) + \\ & \alpha^3 (16(1 + t)^2 - 4(1 + t)^2 (8 + t)\beta + t(4 + t + 2t^2)\beta^2 + 4(8 + t(17 + t(13 + 2t)))\beta^3 - \\ & (16 + t(36 + t(29 + 6t)))\beta^4) - 4\alpha(-1 + \beta)^2 (1 + \beta)(-2 + 6\beta + t(2 + 3\beta)) \end{aligned} \quad (A1)$$

$$c_3 = \frac{-2+\beta}{(1+t)(-2+\beta^2)} - \sqrt{\frac{4\beta-\beta^2-\beta^3}{(1+t)^2(1+\beta)(-2+\beta^2)^2}} \quad (A2)$$

$$c_4 = \frac{-2+\beta}{(1+t)(-2+\beta^2)} - \sqrt{2} \sqrt{\frac{(-1+\beta)X_1}{(1+t)^2(1+\beta)(-2+\beta^2)^2 Y_1}} \quad (A3)$$

$$\alpha_2 = \frac{2(-1+\beta)X_2}{t^2\beta^2(-20-4t+20\beta+5t\beta)} - 2 \sqrt{\frac{(-1+\beta)Y_2}{t^4\beta^4(-20-4t+20\beta+5t\beta)^2}} \quad (A4)$$

where:

$$X_1 = 4(2 + \beta - \beta^2)^2 - 4\alpha(1 + \beta)(8(1 + t) - 2(2 + t)\beta - 5(1 + t)\beta^2 + (3 + 2t)\beta^3) + \alpha^2(t^2(4 + \beta - 2\beta^2)^2 + 4t(1 + \beta)(-4 + 3\beta)(-2 + \beta^2) + 8(2 - 3\beta^2 + \beta^4)) \quad (A5)$$

$$Y_1 = (1 + t)\alpha + \alpha(-8 + t(-8 + t\alpha))\beta^2 + 8(-1 + \beta^2) \quad (A6)$$

$$X_2 = -16 - 16t + 8t\beta + 4t^2\beta + 16\beta^2 + 24t\beta^2 + 5t^2\beta^2 \quad (A7)$$

$$Y_2 = -256 - 512t - 256t^2 + 256\beta + 768t\beta + 640t^2\beta + 128t^3\beta + 512\beta^2 + 1024t\beta^2 + 160t^2\beta^2 - 96t^3\beta^2 - 16t^4\beta^2 - 512\beta^3 - 1536t\beta^3 - 1056t^2\beta^3 - 208t^3\beta^3 - 8t^4\beta^3 - 256\beta^4 - 512t\beta^4 + 96t^2\beta^4 + 96t^3\beta^4 + 11t^4\beta^4 + 256\beta^5 + 768t\beta^5 + 416t^2\beta^5 + 80t^3\beta^5 + 5t^4\beta^5 \quad (A8).$$