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Domestic sourcing vs. Global sourcing: Impact of the exchange rate fluctuation and unreliable domestic supply chain

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Abstract. In high technology industry, it is optional for an original equipment manufacturer (OEM) to purchase semi-finished products directly from contract manufacturer (CM) or import raw materials abroad and entrust CM with processing. Due to various factors such as natural disasters, government's sanctions and backwardness of domestic technology, the domestic supply chain is more fragile than global, while purchasing abroad faces the risk of exchange rate fluctuation. In this paper, we establish a duopoly game model to discuss the trade-offs between the disruption risk of domestic supply chain (ϕ) and the risk of exchange rate fluctuation (μ) from the standpoint of OEM, CM and government. We conclude that firms' win-win situations of profit maximization occur (1) when the expected exchange rate fluctuation is smaller than μ1(ϕ), both OEM and CM prefer global sourcing(GS); (2) when the expected exchange rate fluctuation is larger than μ2(ϕ), both OEM and CM prefer domestic sourcing(DS).

Keywords: Sourcing strategy; unreliable domestic supply chain; exchange rate fluctuation.

1. Introduction

In high-grade, precision and advanced technique industry, the finished products of an original equipment manufacturer (OEM) need multiple processing procedure and upstream cooperation from contract manufacturer (CM). OEM can buy semi-finished products directly from CM or buy raw materials abroad and then entrust CM to manufacture semi-finished products. For the procurement of semi-finished products, we summarize OEM's trade-offs as follows: (1) Cost. When OEM choose global procurement, it has to bear the risk of exchange rate fluctuation which may increase unpredictable cost. (2) Efficiency. Purchasing domestically has the unique advantage of one-stop-shopping. We recognize the improvement of efficiency as a reduction of unit sourcing cost. (3) Reliability. It is one of the major global issues to take the sustainability of supply chains into consideration for United Nations(Haroon 2021)[1] , however, due to various factors like trade ban, natural disasters, epidemic control and technological gap, domestic supply chain is lack of elasticity especially.

In order to clarify the above points of view, we study the cooperative and competitive supply chain composed of a multinational OEM, a domestic CM, an oversea supplier and a domestic supplier. OEM can either choose to purchase from home or abroad. For the former, OEM purchases semi-finished products directly from CM and pays wholesale price covering the cost of raw materials and manufacturing services, which is called domestic sourcing(DS). For the latter, OEM imports semiconductors from abroad and pays material processing costs, then entrust domestic CM to process semi-finished products, which is called global sourcing (GS). Under both cases, CM has its own brand business. CM's own brand products and OEM's products are substitutable and they compete in the end consumer market. Therefore, CM is not only the upstream cooperator of OEM, but also the downstream competitor.

OEM	→	CM	→	OEM	→	CM
DS/GS		*w/pa*		q_o^{DS}/q_o^{GS}		q_c^{DS}/q_c^{GS}

Fig. 1 Sequence of decision-making

OEM and CM are involved in Cournot competition. The sequence of firms' decision-making is

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shown in Figure1. OEM decides its purchasing strategy firstly, and then CM decides its processing unit price according to the quantity purchased by OEM. Finally, CM can determine the total yield. We use backward reduction method.

2. Literature Review

Our paper mainly focus on two streams of the literature. The analysis of exchange rate fluctuation under the disruption risk of domestic supply chain is the highlight of this paper. On the one hand, a large proportion of papers researches enterprise's sourcing strategies. Varun et al. (2015)[2] study Contingent sourcing under supply disruption and competition. Narges and Seyed (2016)[3] build a triple sourcing supply chain model using a cooperative mechanism under disruption. Further on, Varun and Dmitry (2020)[4] research the dual sourcing under supply disruption. Other researches are related to network design (Hatefi and Jolai 2020)[5], product configuration (Liu et al. 2021)[6] and supplier capability (Abbasi et al. 2021)[7]under supply interruption risk. On the other hand, some papers investigate the impact of exchange rate fluctuation on sourcing strategies, profits allocation, pricing strategies (Liang et al. 2019[8]; Yan et al. 2021[9]) and product architecture (Elif et al. 2021)[10].

These works mainly focus on either the chain breaking risk of domestic procurement or the risk of exchange rate fluctuation, but our work comprehensively considers the exchange rate risk of foreign procurement and the chain breaking risk of domestic procurement, and analyzes the equilibrium conditions of the duopoly model of upstream cooperation and downstream competition, which is the innovation point of the research.

3. Model Setup

3.1 DS strategy

3.1.1 Model analysis

Under DS strategy, OEM outsources both purchasing and initial processing functions to CM, meaning that OEM totally relies on CM and purchases semi-finished products directly from CM. Then OEM reprocesses semi-finished products and sells finished products to the consumer. In this paper, we assume CM can only purchase raw materials from domestic supplier at unit sourcing cost due to supply channels limit. So CM sources raw materials entirely domestically, and sells semi-finished products to OEM at unit price. At the same time, CM can process raw materials into finished products with their own brand and sell them to consumers. Due to the perceived sustainable image on the OEM's global brand which can enhance customers' purchase intention (Leonidas et al. 2021)[11] and customer royalty, OEM enables to sell its products at a premium. In short, OEM tends to be downstream seller and CM tends to be upstream supplier and downstream competitor. The profit of CM consists of two parts, including the profit from selling their own products to consumers and the profit from selling semi-finished products to OEM. The process is shown in Figure 2.

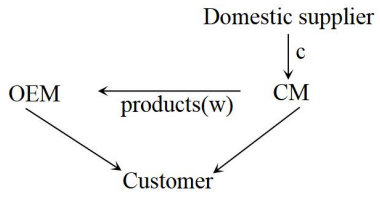

Fig. 2 Domestic sourcing

We assume that OEM pays CM a unit wholesale price w totally, CM's unit sourcing cost is c , and the disruption risk of domestic supplier is ϕ. For domestic sourcing, the upstream supply chain may be disrupted by various events such as production shutdown caused by the prevention and control of epidemic diseases like COVID-19 (Jamal and Salomée, 2021)[12], natural disasters like

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earthquake, government restrictions like trade war and sometimes by quality problems due to domestic technology limit. All values under DS become zero when the domestic supplier cannot provide raw materials. However, for global sourcing, there is almost no possibility of supply chain breakage under global procurement. Thus this paper assumes that the disruption risk of global sourcing is zero. The following will focus on analyzing the situation when OEM choose DS strategy.

Given the duopoly cournot model formula under DS:

Their sales price under DS are as follows:

$$p_o^{DS} = 1+\theta-(q_o^{DS}+q_c^{DS}) \tag{1}$$

$$p_c^{DS} = 1-(q_o^{DS}+q_c^{DS}) \tag{2}$$

Their profits under DS are as follows:

$$\pi_c^{DS} = [q_c^{DS}(p_c^{DS}-c)+q_o^{DS}(w-c)](1-\phi) \tag{3}$$

$$\pi_o^{DS} = q_o^{DS}(p_o^{DS}-w)(1-\phi) \tag{4}$$

So the two companies maximize their respective profits under DS: To maximize the profit of CM, take the partial derivative of (3) with respect to q_c^{DS} and set the equation equal to zero. So the quantity of CM equals to

$$q_c^{DS*}(q_o^{DS}) = \frac{1-q_o^{DS}-c}{2} \tag{5}$$

So:

$$\pi_o^{DS} = q_o^{DS}(1+\theta-q_o^{DS}-q_c^{DS*}(q_o^{DS})-w)(1-\phi) \tag{6}$$

In the same way, we take the partial derivative of (6) with respect to q_c^{DS} and set the equation equal to zero.

$$q_o^{DS*}(w) = \frac{2+2\theta-1+c-2w}{2} \tag{7}$$

Substituting (7) into (5):

$$q_c^{DS*}(w) = \frac{3-2+2\theta-3c+2w}{4} \tag{8}$$

θ stands for brand difference, which is the competitive strength for OEM. q_c^{DS} and q_o^{DS} are sales quantity of CM and OEM under domestic sourcing, p_c^{DS} and p_o^{DS} are sales price of CM and OEM under domestic sourcing and π_c^{DS} and π_o^{DS} are profits of CM and OEM under domestic sourcing.The optimal outcomes are summarized in the Proposition 1.

Proposition 1

When profit is maximized under DS, ***i)***unit wholesale price w is

$$w = \frac{3c+2\theta+3}{6}$$

At this point, firms' sales quantities are

$$q_o^{DS} = \frac{2\theta}{3}$$

$$q_c^{DS} = \frac{3-2\theta-3c}{6}$$

ii)Firms' sales prices are

$$p_c^{DS} = \frac{3-2\theta+3c}{6}$$

iii)Therefore, firms' equilibrium profits are

$$\pi_o^{DS} = \frac{2\theta^2}{9}(1-\phi)$$

$$\pi_c^{DS} = \left[\frac{(-3c-2\theta+3)^2}{36}+\frac{(-3c+2\theta+3)\theta}{9}\right](1-\phi)$$

3.1.2 Equation Analysis

Lemma 1

Under DS, ***i)***expected sales quantity of OEM($E(q_o^{DS})=(1-\phi)q_o^{DS}$) is increasing with θ, while expected sales quantity of CM($E(q_c^{DS})=(1-\phi)q_c^{DS}$) is decreasing with θ ; and both expected sales quantity are decreasing with ϕ;

ii)sales price of OEM is increasing with θ, while sales price of CM is decreasing with θ.

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iii) both firms' profits are increasing with θ.

Now we research the impact of brand difference on firms' decision. It is obvious that OEM can exert the brand influence on end-use market. It can be seen if people pay more attention to the brand, the sales volume of OEM will increase and the price will rise which create lucrative profits. It is contradictory for CM. CM has to take sales promotions under the pressure of OEM's brand premium to guarantee adequate sales. Thus the sales volume of CM decreases and the sales price drops as the brand difference between OEM and CM become greater. However, the profits of CM is an increasing function of brand difference because the profits from processing for OEM become much larger which offsets the negative effects of own brand selling decline.

Then we come to research the impact of disruption risk of domestic supply chain which has negative effects on both OEM and CM. Disruption risk of domestic supply chain means that the domestic supplier can not provide raw materials or the quality of raw materials can not be satisfied. And both OEM and CM have to bear the loss of consumer market which shows as the decline of sales quantity.

3.2 GS strategy

3.2.1 Model analysis

Under GS strategy, OEM imports raw materials from overseas supplier and entrusts CM to process and manufacture semi-finished products, finally carry back semi-finished products from CM and conduct secondary processing. OEM pays CM a unit agency fee*(p_a) (p_a<w)* and pays overseas supplier sourcing cost *d (d>c)*. Similarly, CM' s profit comes from two parts, the profit of semiconductor processing for OEM and the profit of selling products with its own brand. Compared with DS strategy, the difference is that under GS strategy only CM is influenced if domestic supply chain is disrupted. Under global sourcing, OEM can choose substituable overseas supplier quickly with a competitive price. So we assume that the disruption risk of overseas supply chain is zero but OEM has to face the exchange rate fluctuation μ. We use indirect quotation method and set standard of exchange rate fluctuation "1". When μ is greater than 1 , it means depreciation of domestic currency which may lead to a higher sourcing cost for OEM, otherwise it means appreciation of domestic currency which can save OEM's sourcing cost. The real sourcing cost of OEM is μd. The process is shown in Figure 3.

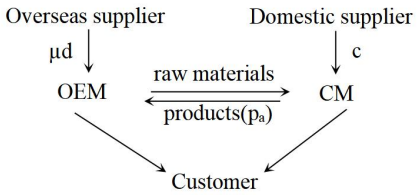

Fig. 3 Global sourcing

Given the duopoly cournot model formula under GS:

Their sales price under GS are as follows:

When the domestic supply chain of CM is disrupted, the inverse demand function only includes OEM:

$$p_o^{GS'} = 1 + \theta - q_o^{GS}$$

Otherwise, the inverse demand function includes both OEM and CM which is the same as DS strategy:

$$p_o^{GS} = 1 + \theta - (q_o^{GS} + q_c^{GS})$$
$$p_c^{GS} = 1 - (q_o^{GS} + q_c^{GS})$$

Their profits under GS are as follows:

$$\pi_o^{GS} = E\left[q_o^{GS}(p_o^{GS'} - p_a - \mu d)\phi + q_o^{GS}(p_o^{GS} - p_a - \mu d)(1-\phi)\right] = E\left[q_o^{GS}\left[p_o^{GS'}\phi + p_o^{GS}(1-\phi) - p_a - \mu d\right]\right]$$
$$\pi_c^{GS} = q_o^{GS} p_a \phi + \left[(q_c^{GS}(p_c^{GS} - c) + q_o^{GS} p_a\right](1-\phi) = q_o^{GS} p_a + q_c^{GS}(p_c^{GS} - c)(1-\phi)$$

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So the two companies maximize their respective profits under GS: The optimal outcomes are summarized in the Proposition 2.

Proposition 2

When profit is maximized under GS, ***i)*** unit agency fee is

$$p_a = \frac{2(1+\theta-\mu d)(3\phi+1)+(1-\phi)^2(1-c)}{2(5\phi+3)}$$

At this point, firms' sales quantities are

$$q_o^{GS} = \frac{2(1+\theta-\mu d-(1-c)(1-\phi))}{5\phi+3}$$

$$q_c^{GS} = \frac{-2(1+\theta-\mu d)+(1-c)(3\phi+5)}{2(5\phi+3)}$$

ii) Firms' sales prices are

$$p_o^{GS} = \frac{3\phi+(5\phi+1)\theta+(7\phi+1)c+2\mu d+3}{2(5\phi+3)}$$

$$p_o^{GS'} = \frac{7\phi+(5\phi+1)\theta+2(\phi-1)c+2\mu d+3}{5\phi+3}$$

$$p_c^{GS} = \frac{3\phi-2\theta+(7\phi+1)c+2\mu d+3}{2(5\phi+3)}$$

iii) Therefore, firms' equilibrium profits are

$$\pi_o^{GS} = \frac{2(\phi+1)(1+\theta-\mu d-(1-c)(1-\phi))^2}{(5\phi+3)^2}$$

$$\pi_c^{GS} = \frac{(1+\theta-\mu d-(1-c)(1-\phi))^2}{5\phi+3}+\frac{(1-\phi)(1-c)^2}{4} \quad (9)$$

The former part in equation (9) is the profit of sales from finished products of its own brand in the end consumer market and the latter part is the profit of processing service of semi-finished products for OEM. To guarantee firms' quantities are greater than zero:

$(1-\phi)(1-c) < 1+\theta-\mu d < \frac{(3\phi+5)(1-c)}{2}$ is required.

3.2.2 Equation Analysis

Lemma 2

Under GS, ***i)*** expected sales quantity of OEM($E(q_o^{GS}) = q_o^{GS}$) is increasing with θ and ϕ and decreasing with μ; while expected sales quantity of CM($E(q_c^{GS}) = (1-\phi)q_c^{GS}$) is decreasing with θ and ϕ and increasing with μ.

ii)sales price of OEM is increasing with θ while sales price of CM is decreasing with θ; and both sales price of OEM and CM is increasing with μ.

iii) both firms' profits are increasing with θ and decreasing with μ.

First, we come to a similar conclusion to Lemma 1 about the impact of brand difference under GS. High brand difference means OEM can sell more products with a higher sales price and CM has to sell at an discount to attract more customers. However, both OEM and CM gain higher profits when OEM owns a greater brand influence.The explanations on Lemma 2 are the same as Lemma 1.

Next, we research the exchange rate fluctuation which can be seen as an incremental sourcing cost (D. Bandaly et al. 2018)[13] or the OEM under GS. As the exchange rate fluctuation μ becomes greater, the real sourcing cost of OEM increases. The increase of μ indicates the depreciation of domestic currency and decline of purchasing power, then the OEM has to buy raw materials of the same volume at the expense of more money. The impact of currency depreciation bumps the unit sourcing cost of raw materials for OEM, so sales price of finished products of OEM increases relatively in which leads to the decline of sales quantity according to demand-supply relations. In equilibrium under GS, the negative effects of higher sales price of OEM overrides the

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positive effects of larger sales quantity of OEM, thus the profit of OEM declines as the exchange rate fluctuation becomes greater. Because OEM holds the market and can decide the sales price, CM is just a follower in which situation CM's sales price of finished products changes with OEM's sales price.When OEM raise its price, CM can also raise its sales price without the increase of production cost. Further on, it is interesting to find that sales quantity of CM increases in spite of the rise of sales price. As exchange rate fluctuation goes up, the products of OEM become so expensive that potential consumers prefer to accept favourable products of CM. Although both the sales price and sales quantity increase with the exchange rate fluctuation, the total profit of CM under GS still declines as the exchange rate fluctuation becomes greater mainly by the decline of agency service with a small processing order size of OEM.

Finally, we research the disruption risk of domestic supply chain. When OEM choose GS strategy, it is clear that the sales quantity of OEM is increasing with the disruption risk of domestic supply chain, under GS OEM can occupy the whole market once the domestic supply chain disrupts. However, it is contradictory for CM. When the disruption risk of domestic supply chain is high, CM suffers from a higher cost compared to the OEM, which also lead to CM's quantity reduction that brings disadvantage to its self-branded business. Recognizing that, CM has the motivation to raise or cut down the agency fee. In detail, the CM can charge a high unit agency fee to gain lucrative profits from processing service while which has a negative impact on the OEM's processing order size, or charge a low agency fee to reduce the unit cost of semi-finished products for OEM which attracts a lager processing order size from OEM indicating that the CM mainly lays on the profits gained by agency service, thus avoiding fierce horizontal competition with the OEM in the end consumer market. In conclusion, the sales price and profits of OEM and CM are related to the level of agency fee of CM considering disruption risk of domestic supply.

The summarize of variables' notation is shown in Table 1.

Table 1. Notation

Variable	Definition
w	OEM pays CM unit wholesale price under GS
pa	OEM pays CM unit agency fee under DS(pa>w)
c	CM's unit sourcing cost
d	OEM's unit sourcing cost(d>c)
ϕ	disruption risk of domestic supplier, where $0\leq\phi\leq1$
μ	exchange rate fluctuation which indicates depreciation of domestic
θ	brand strength for OEM, where $\theta>1$
q_i^{DS}/q_i^{GS}	Superscript DS means domestic sourcing, Superscript GS means global
p_i^{DS}/p_i^{GS}	where i=O represents OEM's sales price, where i=C represents CM's sales price
π_i^{DS}/π_i^{GS}	where i=O represents OEM's profit, where i=C represents CM's profit

4. Discussion

To maximize the interests of shareholders, high profit pursuit of the enterprises has aroused much attention which mainly decides firms' strategies like sourcing, pricing and production decisions. In this part, we research how to maximize the profits of firms based on the fluctuation of exchange rate under different sourcing strategies.

Proposition 3

i)The OEM prefers GS if and only if $\mu<\mu_1$, otherwise OEM prefers DS;

ii)The CM prefers GS if and only if $\mu<\mu_2$, otherwise CM prefers DS.

Proposition 3 indicates that when the expected exchange rate fluctuation is rather large, both OEM and CM prefer DS strategy, on the contrary, GS strategy is better for them when the risk of exchange rate fluctuation is relatively low. From OEM's perspective, when $\mu>\mu_1$, the profit will be maximized when OEM chooses DS strategy. Under this circumstance, OEM is facing rather high

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exchange rate fluctuation, so it will be better for OEM to take DS strategy to avoid the risk of exchange rate fluctuation. However, when $\mu<\mu_1$, GS strategy is more cost-saving and stable so the profit of OEM under GS outweighs under DS.

From CM's perspective, when $\mu>\mu_2$, the profit will be maximized when CM chooses the DS strategy. On the one hand, high exchange rate fluctuation increases the sales price and sales quantity of CM. On the other hand, the order quantity of OEM which constitutes a critical component of CM's profits declines rapidly when exchange rate fluctuation goes up. It can be deduced that the negative impact of reduced order quantity from OEM overrides the positive impact of CM's increased sales quantity and higher sales price under GS. Under this circumstance, CM tends to choose DS strategy. However, when $\mu<\mu_2$, GS strategy can create more profits for CM because OEM will place a larger order under GS.Moreover, it is easy to find $\mu_1<\mu_2$. We make a conclusion of win-win situation about firms' profits in Lemma 3.

Lemma 3

i)Both the OEM and CM prefer GS if and only if $\mu<\mu_1$;

ii)Both the OEM and CM prefer DS if and only if $\mu>\mu_2$.

Lemma 3 indicates the choices of OEM and CM under various conditions in order to ensure the profit is maximized. When the expected exchange rate fluctuation is low, their profits are maximized under GS strategy. It is wise for OEM to source raw materials abroad and entrust CM to process because of lower sourcing cost and stable supply chain. Moreover, CM tends to manufacture large quantity of semi-finished products for OEM instead of selling own products to customers because of the brand difference and lucrative processing commission.

When the condition gets reversed-the expected exchange rate fluctuation is rather high, their profits are maximized under DS strategy. It is wise for OEM to purchase semi-finished products directly from CM although of the disruption risk of supply chain. In above discussion, a great μ will lead to the decline of OEM's order quantity which reduces the profit of CM. So OEM prefers to accept DS strategy to prevent the runoff of processing order.

Thus the conclusion that both OEM and CM choose GS if and only if $\mu<\mu_1$ and choose DS if and only if $\mu>\mu_2$, in which situations their interests coincide and achieve a win-win situation. However, when $\mu_1<\mu<\mu_2$, their interests are contradictory and get a loss-loss situation regardless of the adjustment of other variables. We can see numerical simulation of firms' preference in Figure 4.

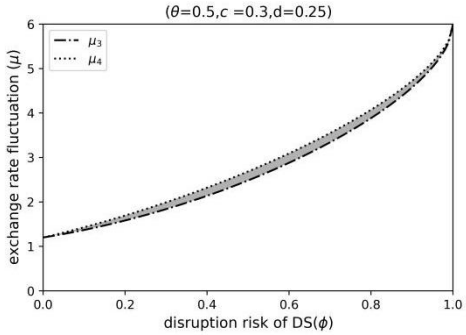

Fig. 4 The OEM's and CM's preference on profit

5. Discussion

The sourcing strategies of firms are critical and complicated because the sourcing cost, the exchange rate fluctuation and supply chain resilience play critical roles in OEM's global supply chain management which dominate CM's sourcing strategy. For the goal of maximizing firms' profits, if the expected exchange rate fluctuation is higher than $\mu_2(\phi)$, both firms prefer DS strategy to avoid the bad impact of exchange rate fluctuation. If the expected exchange rate fluctuation is lower than $\mu_1(\phi)$, both firms prefer GS strategy due to larger sales quantity.

Finally, we provides three feasible research directions in future research which are out the scope of our work due to the use of different modeling methods. First, it is amusing to take upstream

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suppliers' pricing decisions into consideration simultaneously, which is exogenous in our model. Second, there remains some factors worth discussing such as government allowances, tariff and products substitutability. Third, the use of a unique hybrid forecast model or derivative financial instruments can predict and hedge the risk of exchange rate fluctuation(Wang et al. 2021[14]; Joseph et al. 2021[15]), and introducing a exchange rate risk sharing contract between OEM and CM.

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