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空間競爭與代工

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行政院國家科學委員會專題研究計畫成果報告

空間競爭與代工

Spatial Competition and Subcontracting

計畫編號：NSC 92-2415-H-032-016-
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一、中文摘要

本文擴大 Hotelling (1929)**的模型以考慮中間財之代工生產，探討中間財運輸成本為導致最小差異法則成立的因素。本文發現：若中間財與最終財之運輸費率之比率趨近無窮大時，最小差異法則成立；反之，當此比率等於零時，最大差異法則成立。我們也發現，二廠商會聚集在** Stackelber follower **廠商所處之端點，而非** Hotelling **的市場中點。此外，我們証明當固定成本夠高時，代工廠商不會垂直阻絕，而會供給中間財以避免生產太少引起的虧損。**

關鍵詞：空間競爭、事後代工、 Stackelberg **領導廠商**

Abstract

This paper develops a variant of Hotelling's (1929) model involving subcontracting production to explore the possibility of the validity of the principle of Minimum Differentiation. It shows that the equilibrium locations are determined by two opposite forces: a centripetal force that is generated from subcontracting production for saving transportation costs of the subcontracted input, and a centrifugal force that arises from price competition for reducing market competition to earn spatial rents. It also demonstrates that if the transport rate of the subcontracted input is sufficiently large relative to that of the final product, the principle of Minimum Differentiation arises, but the principle of Maximum Differentiation occurs if the condition is reversed. Furthermore, the two firms will locate together at the endpoints of the line market where the rival of the Stackelberg leader locates instead of agglomerating at the center of the line market. This paper also obtains that the fixed cost and the difference of marginal costs are crucial in subcontractor's decisions of vertical foreclosure and supply.

Key Words: Spatial Competition, Ex Post Subcontracting, Stackelberg Leadership

二、緣由與目的

Hotelling (1929) first proposed that two firms of a homogeneous product agglomerate at the center of the line market under linear transportation costs, which has been termed *the principle of Minimum Differentiation.* However, D' Aspremont *et al.* (1979) challenged this principle and showed that the two firms will locate at the endpoints of the line market under quadratic transportation costs. This has been termed *the principle of Maximum Differentiation.*

It is well recognized that all over the industrialized world, subcontracting has become an increasingly popular method

for firms to organize their production in order to enhance competitiveness. Subcontracting production is a way for firms to seek cheaper suppliers to save costs. It is commonly employed in many industries: for example, Ikeda (1989) found that a huge number of the parts of the automobile industry in Japan, the U.S. and Europe are produced by subcontractors. Grossman and Helpman (1999) referred to the 1998 annual report of the World Trade Organization as offering support for the view that only 37 percent of the production value of a representative "American" car is generated in the U.S. Shy and Stenbacka (2003) also pointed out that many firms in the industrialized world subcontract out their productions such as laser printer, PC, mobile phone and aircraft producers. More importantly, there exists close relationship between subcontracting production and location agglomeration in the real world. Scott (1991) empirically studied the geography of the electronics assembly subcontract industry in Southern California and found that electronic assembly subcontractors are strongly linked in networks of transactional interaction with both suppliers and customers, and markedly agglomerate with their main markets. This is fully consistent with the observed location symbiosis between assembly subcontractors and electronic producers.

Unfortunately, to the best of our knowledge, the role of subcontracting production has not been touched upon in the location literature. The present paper aims at filling this gap by developing a variant of Hotelling's (1929) duopoly model where each firm can alter its production cost by subcontracting the production of a key intermediate input.

三、結果與討論

The basic model is a variant of Hotelling's (1929) spatial duopoly model. Assume that there is a linear market of length 1 where consumers are uniformly distributed along the unit interval [0, 1]. Two vertical integrated firms, indexed by 1 and 2, produce a homogenous final product, Q, using a homogenous intermediate input, q. For simplicity, we assume that the production of one unit of the final product needs to employ one unit of the intermediate input. Suppose that subcontracting production arises in the intermediate input market. Firm 1 is the consignor due to having a higher production cost of the intermediate input, while firm 2 is the subcontractor for having a lower production cost of the input. Thus, firm 1 subcontracts out the part or the whole of the production of the intermediate input for saving costs. The location of firm i is denoted by $x_i \in [0, 1]$. The transportation costs of both the final product and intermediate input are assumed to take the form of quadratic functions of distance. Each consumer buys one unit of the final product from the firm with the lower full price, that is, mill price plus transportation cost. Thus, the full price of the final product for a consumer locate at x who buys from firm i is: $p_{if} + t_f (x - x_i)^2$, where p_{if} denotes the mill price of the final product offered by firm i, and t_f is the transport rate of the final product per unit of distance.

Next, with respect to subcontracting decision, we analyze, following Spiegel (1993), *ex post* subcontracting, in which firms engage in a Bertrand price competition in the final product market before they decide whether or not to subcontract production of the input. As Spiegel has argued, this setting is proper and fits the reality. Therefore, the game between firms involves a sub-game

perfect equilibrium with three stages of decision. In the first stage, both firms simultaneously select their locations. In the second stage, the production locations are known and the firms simultaneously choose their mill prices, p_{1f} and p_{2f}, respectively. In the third stage, following Kamien *et al*. (1989), either the consignor or the subcontractor acts as a Stackelberg leader in determining the quantity to be subcontracted and the price of the subcontracted input to be paid to the subcontractor. In this subcontracting stage, we assume that subcontracting would be an equilibrium if no firm is worse off (since there is no transfer payment) and at least one firm better off under subcontracting. The sub-game perfect equilibrium of the model is solved by backward induction, and we start with the final stage.

Ⅲ. The Consignor Acts as a Stackelberg Leader

In this section, we assume that the consignor acts as a Stackelberg leader while the subcontractor as a follower in the intermediate input market. In this setting, the consignor determines the quantity of the input to be subcontracted and the price of the subcontracted input to be paid to the subcontractor in order to maximize his subcontracting profits subject to the subcontractor's opportunity cost, which is represented by his zero subcontracting profits.

We now turn to the second stage to determine the optimal mill prices. Substituting $p_s q_s = c_2 q_s + F$, $q_s = Q_1$, and (2.1) and (2.2) into (3.1) and (3.2), and then differentiating the reduced profit functions with respect to p_{1f} and p_{2f}, setting them equal to zero, respectively.

In the first stage, each firm selects an optimal location to maximize his total profits with the constraints that he has to locate within the interval [0, 1] and $x_1 \leq x_2$.

We can solve for the first-order conditions by the use of Kuhn-Tucker theorem and then obtain the equilibrium locations as follows:

$$x_2^* = 1, \qquad (10.1)$$

$$x_1^* = \frac{3T-1}{3T+3}. \qquad (10.2)$$

We see from (10.1) that the equilibrium location of the subcontractor is at the right endpoint of the line market as the consignor plays a Stackelberg leader. The intuition behind this result is as follows. Actually, there are two opposite forces affecting the firms' location decisions in this model. The first force is the competition effect, which is a centrifugal force that arises from price competition for reducing market competition to earn spatial rents. Since the two firms play a Bertrand price game in the final product market, the price competition between firms will become more severe if the two firms locate closer. This will lead to a lower price of the final product for marginal consumer, and decrease firms' profit from the sale of the final product. Hence, the competition effect will make the two firms tend to locate as far away as possible to earn the spatial rents generated by the existence of the transportation costs of the final product. The second one is the subcontracting effect, which is a centripetal force generated from subcontracting production for saving transportation costs of the subcontracted input. Hence, the subcontracting effect will make the consignor tend to locate closer to the subcontractor to save the transportation costs of the subcontracted input. The equilibrium locations thus hinge upon the relative strength of these two forces. Anticipating that his

subcontracting profits will be completely deprived in the final stage, the subcontracting effect of the subcontractor turns out to be null. The subcontractor will choose to locate as far away as possible from the rival firm (i.e., the consignor) to reduce market competition. Thus, the subcontractor will locate at the right endpoint of the line market. Furthermore, we recognize from equation (10.2) that the equilibrium location of the consignor is a function of the ratio of the transport rates between the subcontracted input and the final product, T, i.e., the trade-off between a centripetal force caused from the transport rate of the subcontracted input and a centrifugal force from the transport rate of the final product. It clearly follows from (11) that the larger the ratio, T, the stronger the subcontracting effect (i.e., the centripetal force) will be. This leads to the result that the consignor will locate closer to the subcontractor. As the ratio approaches infinity, firm 1 will agglomerate with firm 2 at the right endpoint of the line market such that the principle of Minimum Differentiation is valid. On the contrary, when the ratio is no greater than one third, firm 1 will locate at the other endpoint of the line market and then the principle of Maximum Differentiation occurs due to a very weak subcontracting effect.

Ⅳ. Vertical Foreclosure vs. Vertical Supply

In previous section, we have studied firms' location decisions in the case where the subcontractor is willing to supply the intermediate input to his rival. However, the subcontractor would provide no intermediate input to his rival, when his profits are higher under vertical foreclosure than vertical supply. In order to study this vertical foreclosure decision, we need to compare subcontractor's profits between vertical foreclosure and vertical supply.

While taking vertical foreclosure, the consignor is forced to produce his own intermediate input. The subcontracting stage is vanished and the game in question will be reduced to a two-stage game, in which the locations are chosen in the first stage and then firms play Bertrand price competition.

In the case of vertical foreclosure, instead of the subcontracting effect, the centripetal force is represented by the cost-advantage effect, which comes from the difference of marginal costs between firms, because subcontracting production is stopped. The higher the difference of marginal costs, the closer the subcontractor wants to approach to the consignor due to cost advantage. Since there exists no centripetal force for the consignor due to cost disadvantage, he will always locate at the left endpoint of the line market for the possibility of charging a higher price of the final product. When the difference of marginal costs is large (say greater than $(4/3)t_f$), the cost-advantage effect outweighs the competition effect and then the two firms agglomerate at left endpoint. On the contrary, the two firms take apart and locate at the opposite endpoints when this difference is small (say less than t_f). Moreover, the consignor locates at the left endpoint, while the subcontractor in the range (0, 1) when $t_f \le c_1\text{-}c_2 \le (4/3)t_f$.

We find from (16) that the difference of profits is positive and the subcontractor will take vertical supply if the fixed cost is sufficiently large, while taking vertical foreclosure if the fixed cost is sufficiently small and the difference of marginal cost is sufficiently large. When the fixed cost is large, the subcontractor would suffer losses while taking vertical foreclosure

because he would produce a smaller quantity of intermediate input than vertical supply. In contrast, the subcontractor would earn zero profit if taking vertical supply. Consequently, vertical supply is a better choice when the fixed cost is sufficiently large. On the other hand, the subcontractor would choose to locate at the same site of his rival due to cost advantage if the difference of marginal costs is sufficiently large. When the fixed cost is sufficiently small, the subcontractor's profits of vertical foreclosure might outweigh those of vertical supply. This creates an incentive for him to take vertical foreclosure.

Ⅴ. The Subcontractor Acts as a Stackelberg Leader

In this section, we assume instead that the subcontractor plays the role of a Stackelberg leader, while the consignor playing a follower in the intermediate input market. Consequently, the subcontractor determines the subcontract term in the third stage by solving the following problem:

Since the solving process of this case is similar to that in section **Ⅲ**, we shall ignore it here. We also find that the consignor's subcontracting profits are totally deprived by the Stackelberg leader, the subcontractor. The equilibrium locations are derivable as follows:

$$x_1^{**} = 0, \qquad (18.1)$$

$$x_2^{**} = [(8+10T) - 2\sqrt{13T^2+64T+4}]/3(T-1)^2 \quad \text{if } T \neq 1,$$
$$= 4/9 \quad \text{if } T = 1. \qquad (18.2)$$

We see from (18.1) that the equilibrium location of the consignor is at the left endpoint of the line market when the subcontractor plays the role of a Stackelberg leader. The reason for this result is similar to that in previous section. Anticipating that his subcontracting profits will be completely deprived in the final stage, the consignor will locate as far away as possible from the rival firm to reduce the market price competition because the subcontracting effect is absent. Thus, the consignor will locate at the left endpoint of the line market.

In addition, equation (18.2) shows that the subcontractor's equilibrium location depends on the ratio, T, ranging between 0 and ∞. By numerical calculation, we figure out that the equilibrium location declines from $x_2^{**} \approx 1$ as the ratio equals 0.1 to $x_2^{**} = 0$ as the ratio approaches infinity, i.e., $\lim_{T\to\infty} x_2^{**} \approx 0$. Thus, we find that the equilibrium location declines as the ratio rises. Accordingly, we can make the following induction. Being a Stackelberg leader in the subcontracted input market, the subcontractor captures the entire subcontracting surplus incurred in the subcontracting deal. Therefore, the larger the ratio, T, the stronger the subcontracting effect will be. In order to save the transportation costs of shipping the subcontracted input, the subcontractor will locate closer to the consignor. In the extreme case, the subcontracting effect outweighs the competition effect, making the subcontractor agglomerate with the consignor, when this ratio approaches infinity. On the contrary, the subcontracting effect is sufficiently small such that the subcontractor locates at the other endpoint, when this ratio is sufficiently small, say $T = 0.1$. Thus, we can establish the following proposition:

We now turn to study the subcontractor's vertical foreclosure decision when he is a Stackelberg leader in the subcontracting stage. Considering (18.1) and (18.2) and the first-order

condition for location decision, we can derive the subcontractor's profits in the case of vertical supply when he is a Stackelberg leader.

We find from (20) that the difference of profits between vertical supply and vertical foreclosure is positive and the subcontractor will take vertical supply, if the difference of marginal costs is sufficiently large. This arises because the two firms will agglomerate at left endpoint and the subcontractor could only earn the difference of marginal costs minus fixed cost while taking vertical foreclosure. However, the subcontractor's profits of vertical supply are at least greater than the difference of marginal costs while taking vertical supply. On the other hand, when the transport rate of the final good, t_f, is sufficiently small such that the two firms agglomerate at the left endpoint while taking vertical supply, the subcontractor would just be able to earn the difference of marginal costs. Moreover, the two firms would take apart and locate at the opposite endpoints of the line market and could charge higher prices and profits while taking vertical foreclosure, if the difference of marginal costs is below t_f. Accordingly, we obtain the result that the subcontractor would take foreclosure if the difference of marginal costs, the fixed cost and the transport rate of the final good are sufficiently small.

四、計畫成果自評

On self-evaluation, I have completed all of the objectives proposed in the project and found several striking results. They are stated as follows and I think this paper is publishable.

First of all, we show that while taking vertical supply, the principle of Minimum Differentiation arises, when the ratio between the transport rate of the subcontracted input and that of the final product is sufficiently large. On the contrary, the principle of Maximum Differentiation takes place if this ratio is sufficiently small.

Secondly, the two firms will agglomerate at the endpoints of the line market where the rival of the Stackelberg leader locates instead of agglomerating at the center of the line market due to the role of Stackelberg leadership. It is noteworthy that the agglomeration arises at the endpoint of the line market where the rival locates instead of agglomerating at the center of the line market.

Thirdly, we have shown that a small fixed cost is crucial in subcontractor's decision of taking vertical foreclosure. However, the role of the difference of marginal costs between the two firms is ambiguous. A large difference of marginal costs is needed if the subcontractor is a Stackelberg follower in the subcontracted input market, while the condition is reversed if he is a leader.

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