Vertical Outsourcing and Location Choice

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Abstract

Most regional literature focuses on competition among final goods, but little of it integrates an intermediate goods market into the models used. This paper develops a variant of Hotelling’s model involving an intermediate goods market in order to explore the location choices of firms. We consider interactions among three firms: a wholesale supplier of an essential input and two retail producers. One of these retailers is a vertically integrated firm. The other is an independent downstream firm. Within this framework, this paper will discuss the role of strategic vertical outsourcing in determining optimal locations for firms, and it will also explore the input pricing of wholesale suppliers. In general, the two firms were located more closely when the vertically integrated firm had a cost advantage without taking strategic outsourcing into consideration. However, the price of the input may increase when we take strategic vertical outsourcing into account in the model, and this may cause the two firms to move farther away, giving rise to the Principle of Minimum Differentiation.

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Selection and/or peer-review under responsibility of the Organising Committee of ICOAE 2013

Keywords: Spatial competition, Location choice, Outsourcing

1. Introduction

The majority of the previous studies on regional economics have focused on competition in the final goods market only. However, because of the meticulous division of industries, it’s a quite general circumstance that the vertical relation exists in the industrial structure. One such firm is SONY, which not only manufactures input materials such as display panels, but also final products, such as LCD TVs. At the same time, although SONY is a vertically integrated firm, it also still procures display panels from professional panel suppliers, such as AU Optronics Corp. In contrast, VIZIO, one of SONY’s chief competitors, only procures display panels from AU Optronics Corp. to produce LCD TVs, opting not to produce any display panels internally.
Samsung, a mobile phone maker, is another example of a vertically integrated firm, one which manufactures both telecommunication IC and mobile handsets. Its competitor HTC is a company which solely focuses on the production of mobile phones and not on telecommunication IC. However, both Samsung and HTC procure an input, the telecommunication IC, from Qualcomm. Such a market structure, where vertically integrated firms co-exist with independent upstream and downstream firms, is also frequently observed in other industries. This observation led us to wonder what impact such a market structure might exert on the location choices of firms.

In terms of classic regional economics studies, Hotelling (1929) introduced well-known Principle of Minimum Differentiation. D’Aspremont et al. (1979) further assumed a quadratic transportation cost and brought the Principle of Maximum Differentiation. Numerous subsequent scholars adopted the framework laid down by the two early studies and incorporated factors such as heterogeneous products, the spillover effect, market size and public or private enterprises to investigate whether the Principle of Minimum Differentiation is still applicable. Most previous studies were in agreement that under quadratic transportation cost setting, companies would be distributed to the 2 endpoints of the market, which are the points 0 and 1 in the market.

In recent years, a few scholars, such as Brekke and Straumme (2004), Sappington (2005) and Liang and Mai (2006), have combined the notion of vertical market structures with regional economics into a single topic of consideration. Brekke and Straumme (2004) assumed a market with 2 separate downstream firms and 2 upstream firms, and that the downstream firms could only source raw material from one of the upstream firms. In addition, they revealed that in the 3-stage game structure, which determines the optimal position of downstream firms in the first stage, the optimal input price in the second stage and the price of final goods in the third stage, the downstream firms would cluster to the mid-point of the market. Sappington (2005) assumed a market with 2 vertically integrated firms situated at the 2 endpoints of the market, with one of the firms being the incumbent and the other the entrant. The study permitted the entrant to purchase an input from the incumbent firm or self-produce the input. The study described a 3-stage game structure where the optimal input price was determined in the first stage, the entrant undertook a decision in the second stage and the optimal final goods price was determined in the third stage. Under such a game structure, the input procurement decision of the entrant is dependent on price: the entrant would produce the input if it is cheaper to self-produce, or the entrant would purchase the input from the incumbent if it is cheaper to do that.

In looking at these 3 studies, the purpose of vertical outsourcing is a way for firms to seek cheaper suppliers, thus reducing costs. However, procurement of inputs could incorporate strategic behavior. For example, Salop and Scheffman (1983, 1987) considered the vertical outsourcing of firms when the slope of the input supply curve is positive. Chen et al. (2004) investigated the effect of strategic outsourcing when the input market is liberalized. Shy and Stenbacka (2003) and Buehler and Haucap (2006) emphasized that outsourcing can be regarded as a strategic implementation for decreasing market competition. Arya et al. (2008) considered strategic outsourcing under a model framework that includes upstream firms. In other word, downstream firms could reduce their competition against competitors through the purchase of inputs. When a downstream firm makes a purchase of inputs, the derived demand for the input and the input price would increase. This would raise the production costs of downstream competitors and consequently reduce the competition between downstream firms. Therefore, we will combine this effect with the findings of conventional regional economics literature to determine whether the Principle of Maximum Differentiation and the Principle of Minimum Differentiation would still hold.

The remainder of this paper is organized as follows: section 2 develops a basic model. In section 3, the make-or-buy decisions regarding intermediate input for the vertically integrated firm are studied. Section 4 explores the sub-game perfect Nash Equilibrium of the firms’ location choices for each case considered in section 3. The final section contains our conclusions.

2. The model
The basic model is a variant of Hotelling’s (1929) spatial duopoly model. We assume that there is a linear final goods market, represented by the unit interval \([0, 1]\), within which consumers are uniformly distributed. We consider a three firms framework, in which firm \(v\) is a vertically integrated firm competing with downstream firm \(d\) in the linear final good market. They produce the homogenous final product \(Q\), using a homogenous intermediate input. For simplicity, we assume that production of one unit of the final product requires one unit of the intermediate input. In addition, there is a foreign upstream firm \(u\), which is located abroad and only produces inputs. The upstream firm \(u\) sells inputs to downstream firms and \(w\) denotes the price of these inputs. We assume that firm \(d\) doesn’t have the technology to produce the intermediate input. Therefore, firm \(d\) can only purchase inputs from upstream firm \(u\) in order to produce the final good. This assumption was made because the purpose of this paper is to investigate the impact of input outsourcing by a vertically integrated firm on the firm’s location choice. Firm \(v\) can produce intermediate inputs by itself and the production cost of firm \(v\)’s input is denoted by \(c_v\). Supposing that outsourcing arises in the intermediate input market, we can assume that vertically integrated firm \(v\) can make parts of the inputs itself in proportion \(\alpha\) and will outsource inputs from upstream firm \(u\) in proportion \((1 - \alpha)\), where \(\alpha\) is exogenous and \(0 < \alpha \leq 1\).

In this setting, the game between firms involves a sub-game perfect equilibrium with three decision stages. In the first stage, both firms select their locations simultaneously. In the second stage, the upstream firm \(u\) determines the intermediate input price for maximizing its profits. In the third stage, the intermediate input price and production locations are known, while the firms simultaneously choose their mill prices, \(p_v\) and \(p_d\), respectively. The sub-game perfect equilibrium of the model is solved using backward induction, which means we start with the final stage.

The location of vertically integrated firm \(v\) and downstream firm \(d\) are denoted by \(x_i \in [0, 1]\), \(i = v, d\). The transportation costs of the final product are assumed to take the form of quadratic functions of distance. For example, D’Aspremont et al. (1979), Tabuchi and Thisse (1995), Mai and Peng (1999) employed a quadratic form of the transportation cost function. Each consumer buys one unit of the final product from the firm with the lower total price (i.e., the mill price plus transportation cost). Thus, the full price of the final product for a consumer located at \(x\) who buys from firm \(i\) is: \(p_i + t(x - x_i)^2\), where \(p_i\) denotes the mill price of the final product offered by firm \(i\), and \(t\) is the transport rate of the final product per unit of distance. Without a loss of generality, we assume \(x_v \leq x_d\) throughout this paper. When the firms’ locations are set up at \(x_v \leq x_d\), the marginal consumer, who is indifferent between purchasing from either firm, is located at \(\hat{x}\)

\[
\hat{x} = \frac{p_d - p_v}{2t(x_d - x_v)} + \frac{(x_d + x_v)}{2}.
\] (1)

Using equation (1), we can derive total demand for the final goods for firms \(v\) and \(d\), respectively, as:

\[
q_v = \int_0^\hat{x} dx = \hat{x},
\] (2.1)

\[
q_d = \int_\hat{x}^1 dx = 1 - \hat{x}.
\] (2.2)

Where \(q_i (i = v, d)\) denotes firm \(i\)’s total demand. And the firm’s profit function can be expressed as:

\[
\pi_v = \alpha(p_v - c_v)q_v + (1 - \alpha)(p_v - w)q_v,
\] (3.1)

\[
\pi_d = (p_d - w)q_d,
\] (3.2)

\[
\pi_u = (w - c_u)(q_d + (1 - \alpha)q_u).
\] (3.3)

where \(\pi_i (i = v, d, v)\) denotes firm \(i\)’s total profits; \(w\) is the input price.

According to the first-order conditions of firm \(v\) and firm \(d\), we can get the optimal price

\[
p_v = \frac{(3 - 2\alpha)w^p + 2\alpha c_v + t(x_d - x_v)(2 + x_d + x_v)}{3},
\] (4.1)
Substituting equations (4.1) and (4.2) into equations (3.1) and (3.2), results in the following:

\[
\pi_v = \frac{[\alpha(w^v - c_v) + t(x_d - x_v)(2 + x_d + x_v)]^2}{18t(x_d - x_v)},
\]

\[
\pi_d = \frac{[\alpha(w^d - c_v) - t(x_d - x_v)(4 - x_d - x_v)]^2}{18t(x_d - x_v)}.
\]

In the second stage, upstream firm \( u \) selects an optimal intermediate input price for maximizing its total profits. Differentiating that with respect to \( w \), we obtain:

\[
\frac{\partial \pi_u}{\partial w} = \left[ \frac{\partial \pi_u}{\partial q_v} \frac{\partial q_v}{\partial w} + \frac{\partial \pi_u}{\partial q_d} \frac{\partial q_d}{\partial w} \right] + \frac{\partial \pi_u}{\partial w} = 0.
\]

Solving (6), we have:

\[
w = \frac{\alpha^2(c_u + c_v) + t(x_d - x_v)(6 - \alpha(2 + x_d + x_v))}{2\alpha^2}.
\]

Differentiating (7) with respect to \( x_v \), we find that \( \partial w / \partial x_v = -t(3 - \alpha - \alpha c_v) / \alpha^2 < 0 \), \( \partial w / \partial x_d = t(3 - \alpha - \alpha c_d) / \alpha^2 > 0 \). This indicates that if firm \( i \) relocates closer to its rival firm, the effect is a reduction of equilibrium input prices. A closer location implies more competition with regards to output prices between the two firms, and fewer profits for the input supplier to extract through input pricing. In addition, with tougher competition between the two final goods firms, total sales will be more responsive to differentials in the input production costs of the two firms when price competition between the two final goods firms is strong, and this means that the upstream firm will lower the input price. Accordingly, we can establish:

**Proposition 1.** The smaller the distance in location between the two final goods firms, the lower the intermediate input price. The greater the distance in location between the two final goods firms, the higher the intermediate input price.

### 3. The Input Outsourcing Decision for Vertically Integrated Firms

In this section we discuss the optimal outsourcing decisions of an integrated firm with different intermediate goods prices. There are three possible outsourcing decisions that may take place under certain values of input price \( w \): fully outsourcing, partially outsourcing and self-production of all the intermediate goods.

If integrated firm \( v \) makes all the intermediate goods itself, i.e., \( \alpha = 1 \), form (7), we know that the optimal intermediate goods price will be \( w^v = \left[ (c_u + c_v) + t(x_d - x_v)(4 - x_d - x_v) \right] / 2 \), where superscript 1 denotes variables involving firm \( v \) making all of intermediate goods itself. The profits of firm \( v \) under \( w^v \) and \( w^\alpha \) will be

\[
\pi_v^1 = \frac{1}{18t(x_d - x_v)} \left[ \frac{(c_u - c_v) + t(x_d - x_v)(8 + x_d + x_v)}{2} \right]^2,
\]

\[
\pi_v^\alpha = \frac{1}{18t(x_d - x_v)} \left[ \frac{\alpha^2(c_u - c_v) + t(x_d - x_v)(6 + \alpha(2 + x_d + x_v))}{2\alpha} \right]^2.
\]

where superscript \( \alpha \) denotes variables involving partial outsourcing. If the integrated firm \( v \) totally outsources its intermediate goods, the upstream firm \( u \) takes the entire outsourcing surplus, i.e., \( \pi_v^0 = 0 \). And the main results won’t change if firm \( u \) has partial monopoly power.

From (8) and (9), we obtain:
\[ \pi_v^1 - \pi_v^0 = A_1[\alpha(c_u - c_v) - 6t(x_d - x_v)] > (\leq) 0, \text{ if } (c_u - c_v) > (\leq) \theta. \]  

where \( A_1 \equiv (1 - \alpha)[\alpha(1 + \alpha(c_u - c_v) + 2t(x_d - x_v)[3 + 5\alpha + \alpha(x_d + x_v)]]/72\alpha^2t(x_d - x_v) > 0, \theta \equiv [6t(x_d - x_v)] / \alpha. \) From (10), we can establish the following proposition:

**Proposition 2.** The outsourcing decision of vertically integrated firms:

1. Vertically integrated firms would like to produce all of the inputs themselves when they have a large cost advantage, i.e., \( c_u - c_v \geq \theta \), where \( \theta \geq 0 \).
2. Vertically integrated firms would like to strategically outsource parts of their inputs to upstream firms when they still have a cost advantage, i.e., \( 0 \leq c_u - c_v \leq \theta \).
3. Vertically integrated firms would like to outsource parts of their inputs to upstream firms when the upstream firms have a cost disadvantage, i.e., \( c_u - c_v < 0 \).

This proposition is quite different with past regional literatures. Sappington (2005) considered the make or buy decision of input under Hotelling’s (1929) framework, in which two vertically integrated firms have different production costs. He finds that the firm undertakes an efficient make-or-buy decision if it purchases the inputs from another firm whenever that other firm is the least-cost supplier of the input. On the other hand, it produces the inputs itself whenever it is the least-cost supplier of the input. In our paper, the strategic outsourcing behavior of vertically integrated firms occurs due to their consideration of upstream and downstream firms. Therefore, vertically integrated firms purchase their inputs from upstream firms even when they are the least-cost suppliers of the input, since they want to enhance the input price of rival firms. Our result is in sharp contrast with Sappington’s conclusion. In addition, Liang and Mai (2006) assumed two vertically integrated firms in the linear market. In this case, when one of the firms has a higher marginal cost, it can lower this marginal cost by subcontracting all or a part of the production of a key input to the other. Therefore, they never consider the possibility of strategic outsourcing.

### 4. The firms’ location equilibria

We now proceed to investigate the optimal location of two firms in the above cases. Total differentiating that with respect to \( x_i \), we obtain:

\[ \frac{d\pi_v}{dx_v} = \frac{\partial \pi_v}{\partial p_v} \frac{\partial p_v}{\partial w} \frac{\partial w}{\partial x_v} + \frac{\partial \pi_v}{\partial p_v} \frac{\partial p_v}{\partial x_v} + \frac{\partial \pi_v}{\partial x_v}; \quad \frac{d\pi_d}{dx_d} = \frac{\partial \pi_d}{\partial p_v} \frac{\partial p_v}{\partial w} \frac{\partial w}{\partial x_d} + \frac{\partial \pi_d}{\partial p_v} \frac{\partial p_v}{\partial x_d} + \frac{\partial \pi_d}{\partial x_d}. \]  

The first-term on the right side of (11.1), with a non-positive value, and of (11.2), which is non-negative, and this is named the strategic location effect. This effect can increase profits thanks to its enhancement of the input price and the price of the rival firm by moving away from the rival firm. The second-term is on the right side of (11.1), the value of which is non-negative, and of (11.2), which is non-positive, and this is called the input price effect. This indicates that the input price decreases as the two firms become less distant, and therefore the profit increases. The third-term is on the right side of (11.1), the value of which is non-positive and of (11.2), which is non-negative, and these are named the competition effect. This indicates that the more distant the two firms get, the more dissimilar their transport costs from any site become, and therefore competition is lessened under Bertrand price competition. Finally, the forth-term on the right-side of (11.1), the value of which is non-negative, and of (11.2), which is non-positive, are called the hinterland effect. This effect can increase the hinterland of the firm by moving near the rival firm. Consequently, these four effects jointly determine two firms’ equilibrium locations.
Case 1: $\alpha \in (0,1)$ and $c_u - c_v < 0$

From (11.1) and (11.2), we can rewrite the equation as follows:

$$\frac{d\pi_v}{dx_v} = t(x_d - x_v)[-2(3 + \alpha) - \alpha(3x_v - x_d)] + \alpha^2(c_u - c_v) < 0,$$  \hspace{1cm} (12.1)

$$\frac{d\pi_u}{dx_u} = t(x_d - x_u)[-2(3 - 5\alpha) - \alpha(3x_u - x_d)] + \alpha^2(c_u - c_v).$$  \hspace{1cm} (12.2)

From (12.1) and (12.2), we obtain

$$x_v^* = 0,$$  \hspace{1cm} (13.1)

$$x_d^* = \begin{cases} 
(1/3\alpha)[t(5\alpha - 3) + \sqrt{t^2(5\alpha - 3)^2 + 3\alpha^2t(c_u - c_v)}] & \text{if } c_1 < c_u - c_v < 0 \\
0 & \text{if } c_u - c_v < c_1. 
\end{cases}$$  \hspace{1cm} (13.2)

where $c_1 \equiv (-t / 3\alpha^2)(5\alpha - 3)^2 < 0$. From (13.1) and (13.2), we can establish the following proposition.

**Proposition 3.** If the integrated firm outsources parts of its inputs to the upstream firm to reduce the production costs (i.e., $c_u - c_v < 0$), we have:

1. If $c_1 - c_v < c_v$, the Principle of Minimum Differentiation (i.e., $x_v^* = x_d^* = 0$) holds, and the downstream firm and the vertically integrated firm congregate at the left endpoint of the line market instead of at the center of the line market.
2. If $c_1 < c_u - c_v < 0$, where $c_1 \equiv (-t / 3\alpha^2)(5\alpha - 3)^2$, the firms’ location equilibria are $x_v^* = 0$ and $x_d^* = (1/3\alpha)[t(5\alpha - 3) + \sqrt{t^2(5\alpha - 3)^2 + 3\alpha^2t(c_u - c_v)}]$, the Principle of Maximum Differentiation does not hold.

Next, we investigate the firms’ location equilibria when $0 \leq c_u - c_v \leq \theta$.

Case 2: $\alpha \in (0,1)$ and $0 \leq c_u - c_v \leq \theta$.

From (12.1) and (12.2), the firms’ location equilibria are still the same with case 1 although $c_u - c_v$ is positive but its value is not large enough. When the cost differential between firm $u$ and firm $v$ is large enough, solving (12.1) and (12.2), we get that:

$$\begin{cases} 
\begin{array}{l}
x_v^* = \left[\alpha^2(c_u - c_v) - 18t + 3\alpha t\right] / 6\alpha t \\
x_d^* = 1 
\end{array} \text{ if } c_2 < c_u - c_v < \theta. 
\end{cases}$$  \hspace{1cm} (14)

Where $c_2 \equiv [3t(6 - \alpha)] / \alpha^2$.

Thus, we can establish the following proposition:

**Proposition 4.** If the integrated firm outsources parts of its inputs to an upstream firm for strategic purposes (i.e., $0 \leq c_u - c_v < \theta$), we have:

1. If $0 < c_u - c_v < c_2$, where $c_2 \equiv [3t(6 - \alpha)] / \alpha^2$, the firms’ location equilibria are $x_v^* = 0$ and $x_d^* = (1/3\alpha)[t(5\alpha - 3) + \sqrt{t^2(5\alpha - 3)^2 + 3\alpha^2t(c_u - c_v)}]$.
2. If $c_2 \leq c_u - c_v < \theta$, the firms’ location equilibria are $x_v^* = \left[\alpha^2(c_u - c_v) - 18t + 3\alpha t\right] / 6\alpha t$ and $x_d^* = 1$.

Next, we move on to study the case in which an integrated firm decides to produce the inputs itself when $c_u - c_v \geq \theta$. 
Case 3: \( \alpha = 1 \) and \( c_u - c_v \geq \theta \).

Substitute \( \alpha = 1 \) into (11.1) and (11.2) and solve them, we can get

\[
xd^* = 1, \quad (15.1)
\]

\[
x_v^* = \begin{cases} 
\left(1/3t\right)[-2t + \sqrt{25t^2 - 3t(c_u - c_v)}] & \text{if } \theta \leq c_u - c_v \leq 7t \\
1 & \text{if } c_u - c_v > 7t 
\end{cases}, \quad (15.2)
\]

Where \( \theta \equiv 10t - 2 \sqrt{25t^2 - 3t(c_u - c_v)}. \)

Therefore, we can establish:

**Proposition 5.** If the integrated firm decides to produce all inputs itself, to specified (i.e., \( c_u - c_v \geq \theta \)), we have:

1. If \( \theta \leq c_u - c_v \leq 7t \), the firms’ location equilibria are \( x_v^* = (1/3t)[-2t + \sqrt{25t^2 - 3t(c_u - c_v)}] \) and \( x_d^* = 1. \)
2. When \( c_u - c_v \geq 7t \), the vertically integrated firm becomes a monopolist and the Principle of Minimum Differentiation is not sustainable.

Comparing our result with the Principle of Maximum Differentiation as derived by D’Aspremont et al. (1979), we find that the Principle of Maximum Differentiation never occurs by taking an upstream firm into account, even if vertical outsourcing production is absent.

5. Conclusion

This paper has developed a variant of Hotelling’s (1929) model involving vertical outsourcing to explore the validity of the Principle of Minimum Differentiation. The vertically integrated firm can choose to outsource parts of its input to an upstream firm or to produce all of the input itself. Several interesting results are derived accordingly.

We have shown that the smaller (greater) the distance in location between the two final goods firms, the lower (higher) the intermediate input price. Secondly, we have shown that taking into account the outsourcing production, the Principle of Minimum Differentiation increases in the case where the vertically integrated firm outsources parts of its input so as to reduce its production cost. Moreover, the integrated firm has an incentive to outsource parts of its input to an upstream firm even if its marginal cost is lower than that upstream firm. This arises for the purpose of increasing the input price of the integrated firm’s rival. In this case, the integrated firm tends to be located as far away from its rival as possible, so as to lessen the competition as well as to secure a cost advantage via an increase in its rival’s input price due to the lower cost advantage.

Lastly, in contrast to D’Aspremont et al. (1979), we find that the Principle of Maximum Differentiation may occur by taking an upstream firm and a downstream firm into account.

Reference


