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BILATERAL MONOPOLIES AND LOCATION CHOICE

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Bilateral monopolies and location choice*

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Abstract

We analyse how equilibrium locations in location-price games à la Hotelling are affected when firms acquire inputs through bilateral monopoly relations with suppliers. Assuming a duopoly downstream market, we consider the case of two independent input suppliers bargaining with both downstream firms. We find that the presence of input suppliers changes the locational incentives of downstream firms in several ways, compared with the case of exogenous production costs. Bargaining induces downstream firms to locate further apart, despite the fact that input prices increase with the distance between the firms. In the case of asymmetrical bargaining strengths, the downstream firm facing the stronger input supplier has a strategic advantage and locates closer to the market centre. Sequential location introduces a first-mover advantage which may be mitigated or reinforced, depending on whether or not it is the first mover that bargains with the stronger input supplier.

Keywords: Spatial competition; Location choice; Bilateral monopolies; Endogenous production costs.

JEL classification: L13, J51, R30

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1 Introduction

In most models of endogenous location, interpreted either in geographical space or product space, firms are assumed to base their choice of location on a trade-off between capturing a larger share of the market and avoiding more intense competition. The former consideration would induce firms to locate close to each other, whereas the latter would point in the direction of the opposite. In the present paper we analyse a situation in which locational choice also affects firms' production costs. We do so by modelling a duopoly in which downstream firms acquire inputs through bilateral monopoly relations with upstream input suppliers. Input prices are determined in simultaneous bargaining between each firm and its input supplier.

Such bilateral monopoly relations are an important feature of several industries (see e.g. Horn and Wolinsky, 1988). The most obvious example is probably that of a firm with a unionised labour force, where wages are determined in bargaining between the firm and its trade union. When analysing the location choices of downstream firms in this type of industry structure, we make the important assumption that production technologies are independent of locations in the downstream market. This essentially means that for a given technology, which locks a downstream firm into a bilateral monopoly relation with an upstream input supplier, each downstream firm has a feasible (non-empty) strategy space in terms of location, implying that the same input can be used at different locations. If location is interpreted in geographical space (e.g. the 'linear city'), the reasonableness of this assumption should be obvious, and even if we think of location as horizontal product differentiation it would be reasonable to assume that a given technology facilitates a possibly large scope for differentiation. This assumption should be especially viable in the context of labour input with a certain degree of general skills.[1]

The structural contents of the model resemble that of Horn and Wolinsky (1988), who study the incentives for merger in such industries. Our concern is quite different, though, since we are interested in how such bilateral monopoly relations affect the downstream firms' choice of location. The crucial aspect of the model is the endogenisation of production costs. Since different locations will yield different bargaining

[1] In the light of this discussion, standard models of location with exogenous and constant marginal costs should be interpreted as implicitly relying on the same kind of assumption about the independence between technology and location. Mayer (2000) relaxes this assumption by allowing for production costs to vary (exogenously) across locations. Assuming segmented markets and discriminatory pricing, this paper is quite different from ours, though.

outcomes, the choice of location is not only governed by considerations for market shares and the degree of inter-firm competition. Firms must also take into account how their choice of location affects production costs.

Building on the classic work of Hotelling (1929), the 'standard' model of endogenous location is probably D'Aspremont et al. (1979). With uniformly distributed consumers and quadratic transportation costs they established the 'Principle of Maximum Differentiation': Firms will choose to locate at the endpoints of the market. In subsequent years, various attempts to challenge this result have resulted in a sizeable body of theoretical work on this particular subject. The most common research strategy has been to introduce stronger centripetal forces in the model. This can be done in several ways. Neven (1986) and Tabuchi and Thisse (1995) abolish the assumption of uniform distribution, and assume that consumers are more concentrated around the market centre, whereas Böckem (1994) and Rath and Zhao (2001) modify the model to make demand elastic. Wang and Yang (1999) consider location choices when the reservation price is binding (and identical for all consumers). These modifications of the original model are all shown to yield locations 'inside the market'. By introducing R&D externalities between the firms, Mai and Peng (1999) also get similar results. Economides (1986) demonstrates that the principle of maximum differentiation does not hold in general but only for sufficiently convex transportation costs. There exists a range of utility functions such that locations are interior points of the market space. Friedman and Thisse (1993) show that if firms collude on prices they will, in fact, locate at the market centre as Hotelling initially predicted. To our knowledge, though, no attempt has been made to analyse location choices with endogenous production costs.[2]

Our purpose is not to challenge the Principle of Maximum Differentiation. Rather, we want to analyse how bilateral monopoly relations between upstream and downstream firms affect the incentives for relocation in the downstream market, compared with the case in which downstream firms buy their inputs from a competitive upstream market. In order to do so, we choose to apply the standard assumptions of unit demand, uniformly distributed consumers and quadratic transportation costs. Like Lambertini (1994, 1997) and Tabuchi and Thisse (1995), and in contrast to D'Aspremont et al. (1979), we do not confine the firms to choose locations within the market space. This approach,

[2] One notable exception is Gupta et al. (1994), who analyse a location game in which input prices are set by an upstream monopolist. However, using a model of spatial price discrimination their approach is quite different from ours.

which is sometimes referred to as the 'unconstrained Hotelling model', allows us to avoid corner solutions. It is also a way to portray, albeit in a rather crude way, a certain degree of consumer concentration in the market, which seems to be a reasonable assumption, whether location is measured in geographical space or product space.

A priori, it is not obvious whether the endogenisation of production costs turns out to be a centrifugal or centripetal force in the model. Since input prices are increasing in the distance between downstream firms in our model, one should perhaps think that the firms would locate closer in order to lower production costs through increased competition between the input suppliers. However, the model predicts the opposite result: Input suppliers with positive bargaining power always cause the firms to locate further apart. This apparently counter-intuitive result is due to the fact that endogenisation of production costs changes the degree of intensity in price competition between downstream firms as a response to relocation. A relocation in the direction of the rival firm not only reduces the input price for the firm relocating, but also for the rival firm. This makes the centrifugal force of inter-firm competition even stronger than in the case of exogenous production costs.

Analysing the case of asymmetric bargaining strength, we also find that bargaining with a strong upstream firm is a considerable strategic advantage for downstream firms in the location game. The firm with the stronger input supplier will always locate closer to the market than its competitor.

We also extend the basic model by analysing the case in which firms enter the market sequentially. In the case of exogenous production costs, Tabuchi and Thisse (1995) find that the first entrant will locate in the market centre, whereas the follower locates outside the market, revealing a strong first-mover advantage in the location game. Introducing endogenous production costs, though, could alter the locational incentives of the first entrant quite considerably. We find that, in the case of asymmetric bargaining strength, the first-mover advantage will be either reinforced or mitigated, depending on which firm has the strategic advantage of facing the stronger input supplier.

The rest of the paper is organised as follows: Section 2 presents the basic model of simultaneous location choice with two independent input suppliers. In section 3 we analyse how the locational incentives of downstream firms are affected by the endogenisation of production costs, considering the cases of both symmetric and asymmetric bargaining strength. In section 4 we extend the model to look at the case of sequential location choice. In section 5, some of the welfare implications of the model are considered, and, finally, some concluding remarks are offered in section 6.

2 Model

There are two firms selling products 1 and 2 at prices p_1 and p_2, respectively. The products differ with respect to a one-dimensional characteristic, measured by $x \in R$. Whereas x in principle can take any real value, we assume that consumer preferences are characterised by a variable $z \in [0,1]$, implying that consumer k has a 'most preferred product', given by z^k. For simplicity, we assume that z is uniformly distributed on $[0,1]$, with unit mass.

Assuming unit demand, each consumer buys one unit of the good from either of the firms. If consumer k buys the good from firm i, her utility is given by

$$U_i^k = V - p_i - t\left(z^k - x_i\right)^2, \quad i = 1,2 \tag{1}$$

The third term on the right hand side of (1) reflects the disutility associated with buying a product that differs from the consumer's most preferred product. This 'transportation cost' is assumed to be a quadratic function of distance. Consumers maximise utility by choosing to buy the good from the firm with the lower full price, i.e. mill price plus transportation cost. The reservation price V, assumed to be equal across consumers, is sufficiently high for the market always to be covered.

Firms produce the good using an input factor l in a constant-returns-to-scale technology, in which one unit of l produces one unit of output. This technology is assumed to be independent of firms' locations. Inputs are supplied to the downstream firms by independent input suppliers, with the input price w_i being determined in bargaining between firm i and its input supplier. The input suppliers' marginal costs of production are assumed to be equal, and are, without loss of generality, normalised to zero. Both upstream and downstream firms are assumed to be profit maximisers. If we interpret the upstream firms as trade unions, this would correspond to rent-maximising unions.

The profit function of firm i is given by

$$\pi_i = (p_i - w_i)\, Q_i \tag{2}$$

where Q_i is the aggregate demand for firm i's product. We can derive the aggregate demand functions by using the following procedure: Assume, without loss of generality, that $x_1 \leq x_2$. When firms are located at $x_1 \neq x_2$, let the location of the marginal consumer, who is indifferent between buying the good from either firm, be given by $\widehat{z} \in (0,1)$. For this consumer the following equation must hold:

$$p_1 + t\left(\widehat{z} - x_1\right)^2 = p_2 + t\left(x_2 - \widehat{z}\right)^2$$

Solving for $\widehat{z}$, we find the marginal consumer to be located at

$$\widehat{z} = \frac{1}{2}\left(\frac{p_2 - p_1}{t\left(x_2 - x_1\right)} + x_1 + x_2\right) \tag{3}$$

By the assumptions on the distribution of z, aggregate demand for firms 1 and 2, respectively, are given by

$$Q_1 = \int_0^{\widehat{z}} f\left(z\right) dz = \widehat{z} \tag{4}$$

$$Q_2 = \int_{\widehat{z}}^1 f\left(z\right) dz = 1 - \widehat{z} \tag{5}$$

where $f\left(z\right)$ is the density function. Obviously, with uniform distribution on $(0,1)$ and unit mass, $f\left(z\right) = 1$.

Reasonably claiming location choice to be the long term decision of the players, we propose the following sequence of moves in the game:

Stage 1: Firms simultaneously choose their locations, x_1 and x_2.

Stage 2: Input prices w_1 and w_2 are determined in simultaneous and independent bargaining.

Stage 3: Output prices p_1 and p_2 are simultaneously set by the downstream firms.

As usual, the model is solved by backwards induction.

2.1 Stage 3: Price competition

Given the locations of the firms, x_1 and x_2, and the input prices, w_1 and w_2, the firms simultaneously set prices to maximise profits. The first-order condition for firm i is given by

$$Q_i + \left(p_i - w_i\right) \frac{\partial Q_i}{\partial \widehat{z}} \frac{\partial \widehat{z}}{\partial p_i} = 0, \quad i = 1, 2 \tag{6}$$

Substituting (3) and (4)-(5) into (6) and solving yields

$$p_1 = \frac{t}{3}\left(2 + x_1 + x_2\right)\left(x_2 - x_1\right) + \frac{1}{3}\left(2w_1 + w_2\right) \tag{7}$$

$$p_2 = \frac{t}{3}\left(4 - x_1 - x_2\right)\left(x_2 - x_1\right) + \frac{1}{3}\left(2w_2 + w_1\right) \tag{8}$$

2.2 Stage 2: Bargaining

We adopt the Nash bargaining model in a simultaneous bargaining setting, where the players in each bargaining unit negotiate over the input price assuming that an agreement will be reached within the other bargaining unit. For simplicity, the threat points of the bargaining parties are set equal to zero. The solution to the bargaining between firm i and its input supplier is thus given by

$$w_i = \arg\max\,(w_i l_i)^{\alpha_i}\,\pi_i^{1-\alpha_i}, \quad i = 1,2 \tag{9}$$

where $\alpha_i \in [0,1]$ is a measure of the relative bargaining strength of the input supplier of firm i.

Using the anticipated equilibrium prices in the subsequent subgame, (7)-(8), and imposing the technology $l_i = Q_i$, we can solve (9) to find the equilibrium input prices:

$$w_1 = \alpha_1 t\,(x_2 - x_1)\left[\frac{2\,(2 + x_1 + x_2) + \alpha_2\,(4 - x_1 - x_2)}{4 - \alpha_1\alpha_2}\right] \tag{10}$$

$$w_2 = \alpha_2 t\,(x_2 - x_1)\left[\frac{2\,(4 - x_1 - x_2) + \alpha_1\,(2 + x_1 + x_2)}{4 - \alpha_1\alpha_2}\right] \tag{11}$$

2.3 Stage 1: Location choice

At the first stage of the game, the downstream firms simultaneously choose where to locate, each firm taking into account how its location affects input and output prices of both firms in subsequent stages of the game. From (2), the first-order condition for the firm i's optimal choice of location is given by

$$\left(\frac{\partial p_i}{\partial x_i} - \frac{\partial w_i}{\partial x_i}\right) Q_i + (p_i - w_i)\,\frac{\partial Q_i}{\partial \widehat{z}}\,\frac{\partial \widehat{z}}{\partial x_i} = 0, \quad i = 1,2 \tag{12}$$

In order to see how equilibrium locations depend on input prices, we first solve (12) for w_i fixed. Substituting from (3), (4)-(5) and (7)-(8) into (12), letting $\frac{\partial w_i}{\partial x_i} = 0$, and solving, yields

$$x_1 = -\frac{3t + 4\,(w_1 - w_2)}{12t} \tag{13}$$

$$x_2 = \frac{15t + 4\,(w_2 - w_1)}{12t} \tag{14}$$

Finally, using the equilibrium wages in (10)-(11), the equilibrium locations, as functions of relative bargaining strengths, are given by

$$x_1 = \frac{-4 + 8\alpha_1 - 16\alpha_2 + 5\alpha_1\alpha_2}{4(2-\alpha_2)(2-\alpha_1)} \tag{15}$$

$$x_2 = \frac{20 + 8\alpha_1 - 16\alpha_2 - \alpha_1\alpha_2}{4(2-\alpha_1)(2-\alpha_2)} \tag{16}$$

We are now equipped with the necessary expressions to analyse how relocations affect input prices, and conversely, how bargaining over input prices affect the firms' incentives to relocate, compared with the case of exogenous input prices. As a benchmark for comparison, consider the following Lemma:

Lemma 1 *If input prices are exogenous, and equal for both firms, equilibrium locations are given by* $x_1 = -\frac{1}{4}$ *and* $x_2 = \frac{5}{4}$.

Proof. Setting $w_1 = w_2$ in (13) and (14), the result follows immediately. ■

With exogenous input prices, there are two opposing forces governing the choice of location. From the viewpoint of firm i, by moving closer to its competitor the marginal consumer is, *ceteris paribus*, pushed in the same direction, implying that the firm will gain a larger share of the market. This is the *market share effect*, which is a centripetal force in the model. The downside of moving closer to its competitor, though, is that price competition between the firms becomes more intense. Consequently, the *competition effect* is a centrifugal force in the model.

Lemma 1, which is a replication of the result in Lambertini (1994, 1997) and Tabuchi and Thisse (1995), shows the strength of the centrifugal force, with the firms choosing to locate outside the market. In the context of our model, exogenous input prices would correspond to the case in which the downstream firms have all the bargaining strength, and could be interpreted as the firms buying inputs from a competitive upstream market, or being vertically integrated with their respective input suppliers.

3 Location choice with input price bargaining

When input prices are endogenous, the downstream firms must take into account how the outcome of input price bargaining is affected by the firms' locations. In order to analyse the effect of input price bargaining on locational incentives, we start by considering the special case in which both firms bargain with equally strong input suppliers, i.e. $\alpha_1 = \alpha_2$.

3.1 Symmetric bargaining power

When input suppliers have identical bargaining strength, input prices will be identical in equilibrium, and equilibrium locations must necessarily be symmetric. The effect of input prices on the distance between firms in symmetric locations can be found from (10) and (11).

Lemma 2 *In symmetric locations, equilibrium input prices are increasing in the distance between firms.*

Proof. Setting $\alpha_1 = \alpha_2 = \alpha$ and $x_2 = 1 - x_1$ in (10) and (11), we find that $\frac{\partial w_1}{\partial x_1} = \frac{\partial w_2}{\partial x_1} = -\frac{6t\alpha}{2-\alpha} < 0$. ■

Thus, when firms are located closer together, they are able to obtain lower input prices in bargaining. This is a very intuitive result. Closer location implies a more fierce competition on output prices between the downstream firms, and thus there are less profits for the input suppliers to extract through bargaining. In addition, tougher competition between the downstream firms implies that input suppliers also compete more fiercely, implying that the upstream firms will be more reluctant to push for high input prices, since total sales are more responsive to input price differentials when price competition between downstream firms is strong.

It would seem that Lemma 2 points to a centripetal force that should make the firms locate closer together, and thereby achieving lower production costs. As the following proposition shows, though, this is not the case.

Proposition 1 *The presence of input suppliers with positive (and equal) bargaining strength implies that the downstream firms will (i) choose to locate even further away from the market and (ii) earn more profits, compared with the case of exogenous input prices.*

Proof. Setting $\alpha_1 = \alpha_2 = \alpha$ in (15) and (16), we find that $\frac{\partial x_1}{\partial \alpha} = -\frac{3}{(2-\alpha)^2} < 0$ and $\frac{\partial x_2}{\partial \alpha} = \frac{3}{(2-\alpha)^2} > 0$. Inserting the equilibrium values of x, w and p into the profit functions (2) yields $\pi_i = \frac{3\left(4-\alpha^2\right)t}{4(2-\alpha)^2}$, $i = 1, 2$. It is then easily verified that $\frac{\partial \pi_i}{\partial \alpha} = \frac{3t}{(2-\alpha)^2} > 0$. ■

The intuition behind this apparently counter-intuitive result is traced by examining how input price changes affect the intensity of price competition between downstream firms. Relocation of a firm in the direction of its competitor is a way to reduce own production costs, but it also contributes to reduce the production costs of its rival firm. Since prices are strategic complements, price competition between downstream firms is intensified. Thus, the *competition effect* from closer location is *stronger* when input prices are endogenous, and this more than offsets the gain from lower production costs. This means that, by relocating in opposite directions, the increase in output prices, due to relaxed competition between the downstream firms, is larger than the increase in input prices.

The latter fact implies that profits in the downstream market are higher when the firms are faced with bargaining over input prices. Thus, downstream firms would actually prefer having biletaral monopoly relations with independent input suppliers, rather than facing a competitive upstream market or being vertically integrated with their respective input suppliers. The reason is that the bargaining process serves as a credible device for softening price competition in the downstream market, yielding a higher total profit in the market.

3.2 Asymmetric bargaining power

The previous subsection showed that input price bargaining introduces two opposing forces on relocation incentives for downstream firms. Relocation by firm i in the direction of firm j leads to a reduction in production costs for firm i, which implies both a direct cost saving and, *ceteris paribus*, an improved competitive position towards firm j. But such a relocation also leads to reduced production costs for firm j, which results in a more fierce price competition. With equally strong input suppliers we showed that this second effect dominates, and relocation towards the centre of the market is ultimately negative, in terms of profits, for both firms.

The relative strength of the two effects, though, is determined by input price responses to relocation, which in turn is determined by the relative bargaining strength of the input suppliers. The marginal effects of changes in relative bargaining strengths on relocation incentives are summarised in the following lemma:

Lemma 3 *An increase in the relative bargaining strength of input supplier i (input supplier j) will give firm i an incentive to relocate towards (away from) firm j.*

Proof. Taking partial derivatives in (15)-(16), we find that $\frac{\partial x_1}{\partial \alpha_1} = \frac{3}{2(2-\alpha_1)^2} > 0$, $\frac{\partial x_1}{\partial \alpha_2} = -\frac{9}{2(2-\alpha_1)^2} < 0$, $\frac{\partial x_2}{\partial \alpha_2} = -\frac{3}{2(2-\alpha_2)^2} < 0$, $\frac{\partial x_2}{\partial \alpha_1} = \frac{9}{2(2-\alpha_2)^2} > 0$. ■

Input suppliers would optimally want to respond to relocations by adjusting their prices to maximise profits at all times. The extent to which they are able to do so is determined by their relative bargaining strengths. It is thus clear that input price *responses* to relocations are increasing with the relative bargaining strengths of upstream firms. From the viewpoint of firm i, a strong response by its own input supplier and a weak response by the input supplier of firm j means that firm i can improve its competitive position by relocating in the direction of its rival firm. For firm j, the incentives are opposite.

The important implication of these incentive mechanisms is that bargaining with a *strong* input supplier is a *strategic advantage* for downstream firms in the location game. To make this point more clear, consider the limit case in which only one of the downstream firms, say firm 1, has to enter into bargain with an upstream firm. This would correspond to the case of $\alpha_2 = 0$.[3] Consider now the relocation incentives of firm 1. By moving closer to firm 2 it can reduce its production costs without reducing the production costs of firm 2, thus unambiguously improving its competitive position relative to its competitor. Firm 2, on the other hand, has exact opposite incentives. Remember that the input price of firm 1 is negatively related to the degree of competition between the downstream firms. Thus, firm 2 can induce an *increase* in the production costs of firm 1 by moving further away. We then have the following results:

Proposition 2 *Input suppliers with unequal relative bargaining strengths implies that (i) firm i will locate closer to (further away from) the market centre than firm j if* $\alpha_i > (<) \, \alpha_j$*, and (ii) the distance between firms is increasing in* α_i *and* α_j*.*

Proof. (i) Let $A \equiv \frac{1}{2} - x_1$ and $B \equiv x_2 - \frac{1}{2}$ be measures of the "distance from the market" for firms 1 and 2, respectively. Without loss of generality, assume that $\alpha_1 > \alpha_2$. From (15) and (16) we find that $A - B = \frac{6(\alpha_2 - \alpha_1)}{(2-\alpha_1)(2-\alpha_2)} < 0$.

(ii) Since $x_1 \leq x_2$, it is sufficient to compare the partial derivatives; $\frac{\partial x_2}{\partial \alpha_1} - \frac{\partial x_1}{\partial \alpha_1} = \frac{3}{(2-\alpha_1)^2} > 0$ and $\frac{\partial x_2}{\partial \alpha_2} - \frac{\partial x_1}{\partial \alpha_2} = \frac{3}{(2-\alpha_2)^2} > 0$. ■

The first part of the proposition, which follows naturally from Lemma 3, demonstrates the strategic advantage of meeting a strong upstream firm in bargaining. Although the firm facing the stronger input supplier will have higher production costs, the locational incentives are such that this firm will locate closer to the market than its competitor, allowing the firm to charge a higher price for its final product.

Inserting the equilibrium values of x, w and p into the profit functions, (2), we find equilibrium profits in the full game to be

$$\pi_1 = \pi_2 = \frac{3}{4} \frac{(4 - \alpha_1 \alpha_2) \, t}{(2 - \alpha_1)(2 - \alpha_2)} \tag{17}$$

[3] Alternatively, this situation could be interpreted as firm 2 being vertically integrated with its input supplier, implying an input price equal to marginal production costs, i.e. $w_2 = 0$. It can easily be verified that this would yield the same result.

Thus, it turns out that the strategic advantage of having the stronger input supplier always exactly offsets the cost disadvantage.

Regarding the distance between the firms' equilibrium locations, we know from Lemma 3 that an increase in the relative bargaining power of one of the input suppliers provides the corresponding downstream firm with an incentive to relocate towards its rival. *Ceteris paribus*, this leads to a smaller distance between the firms. However, we also know from Lemma 3 that the optimal response of the rival firm is to relocate further away, in order to credibly soften price competition through higher input prices. The second part of Proposition 2 shows that that this second effect is always stronger, implying that the distance between the firm is increasing in the relative bargaining strength of either input supplier.

Comparing with the benchmark (Lemma 1), the strategic implications in the location game of input suppliers with unequal relative bargaining strength are given in the following proposition:

Proposition 3 *Compared with the case of exogenous input prices, (i) firm i locates closer to the market centre if $\alpha_i > 0$ and $\alpha_j = 0$, or if the difference between α_i and α_j is sufficiently large, and (ii) the distance between the firms is always larger with endogenous input prices.*

Proof. (i) Firm 1 locates closer to the market than in the benchmark case (see Lemma 1) if $x_1 > -\frac{1}{4}$. From (15), we find that this is true if $\alpha_1 > \frac{3\alpha_2}{1+\alpha_2}$.

(ii) Let $C \equiv x_2 - x_1$ be a measure of the distance between the firms. From (15) and (16) we find that $C = \frac{3}{2}\left(\frac{4-\alpha_1\alpha_2}{(2-\alpha_1)(2-\alpha_2)}\right)$. We see that $C(\alpha_1, \alpha_2) \geq C(0,0)$. ■

The first part of the proposition illustrates the significance of the strategic advantage of facing the stronger input supplier. The downstream firm negotiating input prices with the stronger supplier may, in fact, locate closer to the market centre than in the case of fixed input prices. If the difference in relative bargaining strengths is sufficiently high, the firm with the stronger input supplier will choose to locate inside the market. In the extreme case of $\alpha_1 = 1$ and $\alpha_2 = 0$,[4] equilibrium locations are given by $\left(x_1 = \frac{1}{2}, x_2 = \frac{7}{2}\right)$. This resembles the outcome of sequential location in Tabuchi and Thisse (1995), where the first-mover locates at the market centre and the follower locates outside the market. In the subsequent section we will reconsider the case of sequential location in the light of the present model.

[4] In the context of labour input, this would correspond to a situation in which firm 1 is unionised (with a monopoly union), whereas firm 2 is non-unionised.

The second part of the proposition follows necessarily from Proposition 2, and confirms that bilateral monopoly relations with upstream suppliers still serves as a device to dampen the degree of competition in the downstream market, even in the asymmetric case.

4 Sequential location

In some markets it may be more realistic to assume that firms enter the market sequentially, while bargaining and price competition remain simultaneous. In this particular extension of the model the game is now played in four stages. Firm 1 enters the market first, followed by the locational choice of firm 2 in the second stage of the game. In the third stage input prices are simultaneous determined through bargaining, whereas output prices are set in the final stage of the game.

As before, the natural benchmark for comparison is the case of exogenous input prices. From Tabuchi and Thisse (1995) we know that in this case there is a strong first-mover advantage, yielding $\left(x_1 = \frac{1}{2}, x_2 = \frac{3}{2}\right)$ as the equilibrium outcome.

Equilibrium locations when firms enter sequentially are derived by backwards induction, starting at stage 2 of the game. The first order condition for firm 2's locational decision is given by

$$\frac{\partial \pi_2 \left(x_1, x_2\right)}{\partial x_2} \equiv \left(\frac{\partial p_2}{\partial x_2} - \frac{\partial w_2}{\partial x_2}\right) Q_2 + \left(p_2 - w_2\right) \frac{\partial Q_2}{\partial \widehat{z}} \frac{\partial \widehat{z}}{\partial x_2} = 0 \qquad (18)$$

yielding a best-reply function

$$x_2 = R\left(x_1\right)$$

At the first stage of the game firm 1 enters the market, anticipating the response of the follower. Thus, the first-order condition for the optimal location of firm 1 is given by

$$\frac{\partial \pi_1 \left(x_1, R\left(x_1\right)\right)}{\partial x_1} + \frac{\partial \pi_1 \left(x_1, R\left(x_1\right)\right)}{\partial R} \frac{dR}{dx_1} = 0 \qquad (19)$$

An important message from the analysis of the previous section, with simultaneous location choice, is that having the stronger input supplier is a strategic advantage in the location game. When location choices are made sequentially, we would thus expect that endogenous input prices and asymmetric bargaining strengths will either mitigate or reinforce the first-mover advantage, depending on which downstream firm has the stronger input supplier.

Using the profit functions and the equilibrium expressions for input and output prices derived in the previous section, the solution to (18) and (19) enables the following statement:

Proposition 4 *When firms enter the market sequentially, firm 1 being the first entrant, then*

(i) firm 1 locates at the market centre if $\alpha_1 \geq \alpha_2$*,*

(ii) firm 1 locates away from the market centre if $\alpha_1 < \alpha_2$*,*

(iii) the firms always locate further apart than if production costs are exogenous.

Proof. (i)-(ii) Observe first that both firms occupying positions at the same side of the market centre cannot be an equilibrium in the location game when consumers are symmetrically distributed. If x_2^* is the best response to $x_1 = \frac{1}{2} - \Delta$, then, due to symmetry, $1 - x_2^*$ must be the best response to $x_1 = \frac{1}{2} + \Delta$. It follows that $\pi_i\left(\frac{1}{2} - \Delta, x_2^*\right) = \pi_i\left(\frac{1}{2} + \Delta, 1 - x_2^*\right)$ for $i = 1, 2$. Thus, it suffices to consider locations where $x_1 \leq \frac{1}{2} \leq x_2$. Solving (18), we find firm 2's best response in the location game to be given by

$$R(x_1) = \frac{1}{3}\frac{(8 + x_1(2 - \alpha_1) + 2\alpha_1)}{2 - \alpha_1} \tag{20}$$

Inserting (20) into the profit function of firm 1 and taking the partial derivative with respect to x_1, we derive

$$\frac{\partial \pi_1(x_1, R(x_1))}{\partial x_1} = \Psi \frac{4 + 4\alpha_1 + \alpha_2\alpha_1 - 8\alpha_2 - 2x_1(2 - \alpha_2)(2 - \alpha_1)}{(4 - \alpha_1\alpha_2)^2} \tag{21}$$

where

$$\Psi = \frac{4}{81}t\left(20 + 2x_1(2 - \alpha_2)(2 - \alpha_1) + 8\alpha_2 - 4\alpha_1 - 7\alpha_2\alpha_1\right)$$

Evaluating for $x_1 \leq \frac{1}{2} \leq R(x_1)$, a closer inspection of (21) reveals that $\partial\pi_1/\partial x_1 > 0$ if $\alpha_1 > \alpha_2$. If $\alpha_1 \leq \alpha_2$, then $\partial\pi_1/\partial x_1 = 0$ for $x_1 \leq \frac{1}{2}$ (with $\partial\pi_1/\partial x_1 = 0$ for $x_1 = \frac{1}{2}$ if $\alpha_1 = \alpha_2$).

(iii) From (20) and (21), equilibrium locations are given by

$$x_1^F = \begin{cases} \frac{4+4\alpha_1+\alpha_2\alpha_1-8\alpha_2}{2(2-\alpha_1)(2-\alpha_2)} & if\ \alpha_1 < \alpha_2 \\ \frac{1}{2} & if\ \alpha_1 \geq \alpha_2 \end{cases} \tag{22}$$

$$x_2^F = \begin{cases} \frac{12+4\alpha_1-8\alpha_2-\alpha_2\alpha_1}{2(2-\alpha_2)(2-\alpha_1)} & if\ \alpha_1 < \alpha_2 \\ \frac{6+\alpha_1}{2(2-\alpha_1)} & if\ \alpha_1 \geq \alpha_2 \end{cases} \tag{23}$$

Now define $D \equiv x_2^F - x_1^F$ as the distance between the firms at equilibrium locations. From (22) and (23) we find that $D = \frac{4-\alpha_1\alpha_2}{(2-\alpha_2)(2-\alpha_1)}$ if $\alpha_1 < \alpha_2$ and $D = \frac{2+\alpha_1}{2-\alpha_1}$ if $\alpha_1 \geq \alpha_2$. Clearly, $D(\alpha_1, \alpha_2) > D(0, 0)$. ■

Proposition 4 illustrates that when downstream firms are locked into bilateral monopoly relations with upstream input suppliers, the location choice of the first entrant is potentially very different from the case of exogenous production costs considered by Tabuchi and Thisse (1995). If $\alpha_1 < \alpha_2$, the first-mover advantage is mitigated by the strategic disadvantage of bargaining with a weak input supplier, causing the first entrant to locate to away from the market centre, with the follower locating closer to the market, making equilibrium locations more symmetric around the market centre. In the extreme case of $\alpha_1 = 0$ and $\alpha_2 = 1$, the follower will actually locate closer to the market centre than the first entrant, with equilibrium locations given by $\left(x_1^F = -1, x_2^F = 1\right)$.

In the opposite case, in which the first-mover also has the strategic advantage of bargaining with the stronger input supplier, the first entrant clearly can do no better than locating at the market centre, but the first-mover advantage is now reinforced in the sense that the follower will locate even further away from the market, compared to the case of exogenous production costs. The intuition follows straightforwardly from the analysis of the previous section.

5 Welfare implications

Having considered the role of input suppliers on the relocational incentives of downstream firms in different market structures, a natural question arises: What are the welfare implications?

Measuring welfare as an unweighted sum of producers' surplus (profits) and consumers' surplus, total welfare is given by

$$W = \sum_{i=1}^{2} \pi_i + \sum_{i=1}^{2} w_i l_i + CS \tag{24}$$

where

$$CS = V - \left(\int_0^{\widehat{z}} \left(p_1 + t\left(z - x_1\right)^2\right) dz + \int_{\widehat{z}}^1 \left(p_2 + t\left(x_2 - z\right)^2\right) dz \right) \tag{25}$$

is consumers' surplus.

With this specification of welfare, an increase in input prices is a monetary transfer from downstream to upstream firms, and with unit demand and non-binding reservation price, an increase in output prices is similarly just a monetary transfer from consumers to downstream firms. This implies that welfare is only determined by total transportation costs. Thus, (24) reduces to

$$W = V - TC \tag{26}$$

where

$$TC=\int_0^{\widehat{z}} t\,(z-x_1)^2\,dz+\int_{\widehat{z}}^1 t\,(x_2-z)^2\,dz \tag{27}$$

is total transportation costs.

Thus, maximising social welfare is equivalent to minimising consumers' transportation costs.[5] In this case we know, as demonstrated by Hotelling (1929), that socially desirable locations require both firms to occupy symmetrical positions at the quartiles of the market, i.e. $x_1=\frac{1}{4}$ and $x_2=\frac{3}{4}$. This means that neither agglomeration in the market centre ('minimal' differentiation) nor locations at the market borders ('maximal' differentiation) are socially desirable. Clearly, when firms locate outside the market, as in the unconstrained version of the Hotelling model, this implies an even larger social loss in terms of increased transportation costs. Examination of transportation costs in equilibrium locations yields the following results:

Proposition 5 *(i) Welfare is always lower with input price bargaining, compared with the case of exogenous input prices.*

(ii) When relative bargaining power is sufficiently asymmetric in favour of input supplier j, an increase in input supplier i's relative bargaining strength raises welfare.

Proof. (i) Inserting equilibrium locations from (15)-(16) into (27) we find that

$$TC=\frac{\left(49\alpha_2^2\alpha_1^2-52\alpha_2^2\alpha_1+448\alpha_2^2-52\alpha_2\alpha_1^2-1016\alpha_2\alpha_1+80\alpha_2+448\alpha_1^2+80\alpha_1+208\right)t}{48(4-2\alpha_1+\alpha_2\alpha_1-2\alpha_2)^2} \tag{28}$$

It follows that $TC(\alpha_1,\alpha_2)-TC(0)=\frac{3}{4}\frac{\alpha_2^2\alpha_1^2+11\alpha_2^2-34\alpha_2\alpha_1+8\alpha_2+11\alpha_1^2+8\alpha_1}{(4-2\alpha_1+\alpha_2\alpha_1-2\alpha_2)^2}>0.$

(ii) Taking the partial derivative in (28) we get

$$\frac{\partial TC(\alpha_1,\alpha_2)}{\partial\alpha_1}=\frac{3}{2}\frac{4+13\alpha_1-11\alpha_2-2\alpha_2\alpha_1}{(2-\alpha_1)^3(2-\alpha_2)}$$

It is then easy to verify that if $\alpha_1>\alpha_2$, then

$$\frac{\partial TC(\alpha_1,\alpha_2)}{\partial\alpha_1}>0$$

[5] Clearly, the assumption of unit demand has some rather strong implications for the analysis of social welfare, making total transportation costs the only relevant variable. It should be said that although this assumption may be a useful approximation for some markets, we would normally expect the 'standard' efficiency loss from pricing above marginal costs to prevail. In this sense, the present welfare analyis is somewhat 'partial', and consequently the results should be interpreted with the necessary degree of care.

and if $\alpha_2 > \alpha_1$, then

$$\frac{\partial TC(\alpha_1, \alpha_2)}{\partial \alpha_1} < (\geq) 0 \quad if \quad \alpha_2 > (\leq) \frac{4 + 13\alpha_1}{11 + 2\alpha_1}$$

■

Downstream firms purchasing inputs through bilateral monopoly relations with suppliers is detrimental to social welfare compared with a situation where inputs are acquired from a competitive upstream market, independent of whether bargaining power is distributed symmetrically or not. The reason is that input price bargaining induces the firms to locate further apart than in the case of exogenous production costs, leading to higher transportation cost for the consumers. In the case of symmetric bargaining strengths this is straightforward, since locations necessarily then are symmetric around the marginal consumer.

In the asymmetric case, it is not that straightforward because the firm facing the stronger input supplier locates closer to the market, possibly even closer than in the case of exogenous production costs. Although the distance between the firms is larger in equilibrium (see Proposition 3) this should not automatically lead to higher total transportation costs if the most centrally placed firm serves the majority of consumers. This is, however, not the case. Inserting equilibrium locations and prices into (3), it is easily confirmed that the marginal consumer is always located at the market centre. In the case of asymmetric relative bargaining strength, the downstream firm facing the stronger input supplier exploits this strategic advantage by charging a relatively high price for the final product, always forcing half of the consumer mass to 'travel' to the more distantly located firm, which charges a lower price.

Let us now consider the case in which firms enter the market sequentially. Using exogenous (and identical) production costs as a benchmark, we know from Proposition 4 that the presence of input suppliers changes the results in two different respects. Due to the effects discussed in section 3, the downstream firms will always locate further apart. *Ceteris paribus*, this leads to an increase in total transportation costs. However, if $\alpha_1 < \alpha_2$, so that the first-mover advantage is partly mitigated by the strategic disadvantage of bargaining with the weaker input supplier, equilibrium locations will be more symmetric around the market centre. This effect should contribute to reducing transportation costs. Thus, whether or not the presence of input suppliers is welfare improving depends on the relative magnitudes of the two effects.

Proposition 6 *Suppose that location choices are made sequentially, firm 1 being the first entrant. If $\alpha_1 < \alpha_2$, there exists a set of parameter val-*

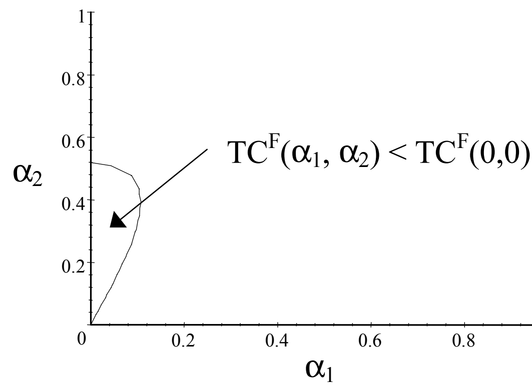

Figure 1: Welfare implications with sequential entry.

ues for which social welfare is higher, compared to the case of exogenous production costs.

Proof. If $\alpha_1 \geq \alpha_2$ we know from Proposition 4 that the first entrant locates at the market centre, and $x_2^F(\alpha_1, \alpha_2) > x_2^F(0,0)$. Obviously, this implies that $TC^F(\alpha_1, \alpha_2) > TC^F(0,0)$. If $\alpha_1 < \alpha_2$, we use (22) and (23), along with equilibrium prices derived in section 2, to calculate

$$\begin{aligned} & TC^F(\alpha_1, \alpha_2) - TC^F(0,0) \\ &= -\frac{t\left(77\alpha_1^2 - 18\alpha_2\alpha_1^2 + 4\alpha_2^2\alpha_1^2 + 104\alpha_1 - 202\alpha_2\alpha_1 + 18\alpha_2^2\alpha_1 - 40\alpha_2 + 77\alpha_2^2\right)}{9(2-\alpha_1)^2(2-\alpha_2)^2} \end{aligned}$$

This expression is plotted in Figure 1, for $\alpha_1 \in [0,1]$ and $\alpha_2 \in [0,1]$. Clearly, $TC^F(\alpha_1, \alpha_2) - TC^F(0,0) < 0$ in the South-West region of the figure. ■

From Figure 1 we see that the presence of input suppliers increases total welfare if both α_1 and α_2 are small, and asymmetric in favour of α_2. This is very intuitive. When both input suppliers are weak, the centrifugal effect of input price bargaining, which is detrimental to social welfare, is quite small. If additionally the follower has the strategic advantage of bargaining with the stronger input supplier, the first-mover advantage is partly mitigated, yielding more symmetric equilibrium locations. When the distance between the firms is not too large, this second effect will dominate, causing social welfare to increase.

6 Concluding remarks

The purpose of this paper has been to consider how bilateral monopoly relations between upstream and downstream firms affect the choice of location (or product differentiation) in the downstream market. The basic model is that of Hotelling with unit demand, uniformly distributed consumers and quadratic transportation costs. Firms choose location on the real line (not restricted to the market) and face endogenous production costs due to the presence of independent input suppliers. We derive the subgame perfect equilibrium location outcomes of the following three-stage game: (i) downstream firms choose location, (ii) input suppliers bargain with downstream firms on input prices, (iii) downstream firms set prices.

The analysis provides the following main results. Firstly, input suppliers induce the downstream firms to locate further apart compared to the case of exogenous production costs. Due to prices being strategic complements, input price bargaining reinforces the centrifugal reduction-of-competition effect, causing firms to locate further apart. A strategic advantage emerges when the firms face input suppliers with different bargaining strengths. In fact, for a sufficient degree of asymmetry, the firm facing the stronger input supplier has an incentive to relocate towards its rival, while the rival has the opposite incentive.

Secondly, considering sequential location the presence of input suppliers potentially changes the results compared to the case of exogenous production cost. In the case of asymmetric bargaining strengths, if the follower has the strategic advantage of facing the stronger input supplier, this effect mitigates the first mover advantage. In the opposite case, the first-mover advantage is reinforced.

Using the interpretation of input suppliers as trade unions, the model offers some hitherto unnoticed arguments concerning the welfare assessment of trade unionism. According to conventional wisdom, trade unions create an efficiency loss by pushing up wages, causing a contraction of employment. Although this effect is not present in our model, due to the specific features of unit demand and non-binding reservation price, we are able to identify an additional, and very different, inefficiency that could potentially arise in unionised industries. In the context of locational choice, the presence of trade unions creates incentives for firms to relocate further away from the market centre, reinforcing the reduction-of-competition effect that causes too much differentiation in the first place.

Finally, it should be noted that in order to facilitate analytical tractability when extending the Hotelling model to incorporate bargaining on input prices, assumptions regarding demand for the final product have been made as simple as possible, with uniform distribution of consumers, unit demand and non-binding reservation prices. With only two downstream firms this implies that the centripetal forces in the model are very strong, perhaps unrealistically strong. As mentioned in the Introduction, there are several ways to incorporate stronger centrifugal forces in the model. For instance, by making demand more elastic one would get locations closer to the market centre. However, our purpose has been to illustrate how the presence of input suppliers affects downstream firms' incentives to relocate, compared to the case of exogenous input prices, and these (partial) effects should be robust to a number of modifications to the original model.

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