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Location of Upstream and Downstream Industries

WORKING PAPERS

Location of upstream and downstream industries

Abstract

This paper studies the issue of agglomeration versus fragmentation of vertically related industries. While the downstream industry works under perfect competition, the upstream industry is a duopoly where each firm supplies a differentiated input to the competitive firms. These process the inputs under a quadratic production function entailing decreasing returns as in PENG, THISSE and WANG (2006). It is found that fragmentation occurs if the transport cost of final goods is medium to high, while the transport cost of inputs is low. Otherwise, agglomeration prevails. Multiple agglomerated equilibria are possible if the transport cost of intermediate goods is either medium or high.

Keywords: Oligopoly; Vertically-Linked Firms; Location; Spatial Fragmentation.

J.E.L.Codes: L13; R10.

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1 Introduction

As AMITI (2005) remarked, the evolution of the location of vertically linked industries exhibits trends of both clustering and fragmentation. For instance, in the textile sector, manufacturing is shifted to low labour cost countries, while design and marketing are placed close to final consumers. This pattern characterizes a wide range of consumer goods industries.

By contrast, in more technologically industries such as the car, aerospace, pharmaceutical and electronics, suppliers an buyers of intermediate goods usually stay close in order to save on transport costs of the inputs, regardless of the labor intensity in their production. In the case of the car industry, producers of parts often co-locate with assembly plants.

The different locational pattern of vertically linked industries can be accounted for by the different transport costs of consumer goods and of intermediate goods. According to PAIS and PONTES (2008), upstream and downstream firms locate in low labor cost countries if the transport costs (both final and intermediate) are low. Fragmentation takes place if the transport cost of intermediate goods is low and the transport cost of final goods is medium to high. Agglomeration in the high labor cost countries occurs if the transport cost of the final good is high. Multiple equilibria (agglomeration of upstream and downstream firms in either country) take place if both transport costs are high.

However PAIS and PONTES (2008) assume a very simple vertical structure, based on a successive monopoly where each firm produces under a fixed proportions, constant returns technology. In this paper, we introduce a more realistic structure, where a duopoly sells differentiated inputs to competitive firms that produce under a decreasing returns quadratic technology inspired in PENG, THISSE and WANG (2006).

In section 1, the assumptions and the structure of the game are described. In section 2, the game is solved. Conclusions are drawn in section 3.

2 The model

We assume a spatial economy with two countries: H(ome) and F(oreign). H is a market point of a consumer good, while F is a low labor cost location. Two upstream firms (U_1 and U_2) supply differentiated inputs to a consumer good industry under perfect competition. We assume that this industry is represented by a single competitive firm D. This firm charges a parametric price, which we assume w.l.g. to be equal to 1.

All transactions of the consumer good are located in a central exchange in country H. If the downstream firm locates in F, its price net of transport cost is given by $1 - \tau$, where τ is the unit transport cost of the consumer good between H and F.

Firms U_1 and U_2 use a unit of labour per unit of output. F is a low labor cost location, so that $w_F < w_H$ where w_F, w_H are wage rates. The upstream firms supply amounts x_1, x_2 of differentiated inputs that are transformed in a homogeneous consumer good according to the following quadratic production firm inspired in PENG, THISSE and WANG (2006):

$$Y\left(x_1, x_2\right) = \alpha\left(x_1 + x_2\right) - \left(\frac{\beta}{2}\right)\left(x_1^2 + x_2^2\right) - \delta x_1 x_2 \qquad (1)$$

with $\alpha > 0, \beta > \delta \geq 0$. In this setting, $\beta - \delta$ measures the degree of sophistication of the productive process, i.e., the degree of differentiation of the inputs. The fact that δ is nonnegative implies that the inputs are substitutes in production. The interregional unit transport cost of the inputs is expressed by t.

Each upstream firm charges a fob mill price, so that its profit function is

$$\pi_i = \left(p_i - w_j\right) x_i, \ \ i = 1, 2; j = H, F \qquad (2)$$

The spatial economy is modelled through a noncooperative game with three stages:

1st Stage Firms U_1, U_2 and D select simultaneously locations in $\{H, F\}$.

2nd Stage Firms U_1, U_2 select prices p_1, p_2 for the intermediate goods.

3rd Stage Firm D selects the amounts to buy of the inputs x_1, x_2 and hence the amount produced

of the final good.

As usual, the game is solved by backward induction in order to find a subgame perfect equilibrium.

3 Solving the game

In what follows, we solve the 3rd stage and the 2nd stage for each set of locations selected by the firms. In order to solve the game quickly, the following parameter specifications are made:

$$\alpha = 10, \beta = 2, \delta = 1 \tag{3}$$

$$w_h = 1, w_f = 0$$

Let (s_1, s_2, s_d) be the vector of locations so that s_i $(i = 1, 2)$ is the location of firm U_i and s_d is the location of firm D. Then the location subgames are as follows.

3.1 Case (H, H, H)

The profit function of the downstream firm is

$$\pi_d = Y - p_1 x_1 - p_2 x_2$$

where Y is given by 1. The profit functions of the upstream firms are given by

$$\pi_1 = (p_1 - w_h) x_1 \tag{4}$$

$$\pi_2 = (p_2 - w_h) x_2$$

Maximizing π_d with relation to x_1, x_2, we obtain the demand functions of the inputs by the downstream firm (bearing in mind 3):

$$x_1 = \frac{1}{3}p_2 - \frac{2}{3}p_1 + \frac{10}{3}$$

$$x_2 = \frac{1}{3}p_1 - \frac{2}{3}p_2 + \frac{10}{3}$$

Substituting these outputs in 4 and maximizing with relation to p_1, p_2, we obtain $p_1 = p_2 = 4$.

3.2 Case (F, H, H)

The profit function of the downstream firm is

$$\pi_d = Y - (p_1 + t)\, x_1 - p_2 x_2$$

where Y is given by 1. The profit functions of the upstream firms are given by

$$\pi_1 = (p_1 - w_f)\, x_1 \tag{5}$$

$$\pi_2 = (p_2 - w_h)\, x_2$$

Maximizing π_d with relation to x_1, x_2, we obtain the demand functions of the inputs by the downstream firm (bearing in mind 3):

$$x_1 = \frac{1}{3}p_2 - \frac{2}{3}p_1 - \frac{2}{3}t + \frac{10}{3}$$

$$x_2 = \frac{1}{3}t + \frac{1}{3}p_1 - \frac{2}{3}p_2 + \frac{10}{3}$$

Substituting these outputs in 5 and maximizing with relation to p_1, p_2, we obtain

$$p_1 = \frac{52}{15} - \frac{7}{15}t$$

$$p_2 = \frac{2}{15}t + \frac{58}{15}$$

3.3 Case (H, F, H)

The profit function of the downstream firm is

$$\pi_d = Y - p_1 x_1 - (p_2 + t)\, x_2$$

where Y is given by 1. The profit functions of the upstream firms are given by

$$\pi_1 = (p_1 - w_h)\, x_1 \tag{6}$$

$$\pi_2 = (p_2 - w_f)\, x_2$$

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Maximizing π_d with relation to x_1, x_2, we obtain the demand functions of the inputs by the downstream firm (bearing in mind 3):

$$x_1 = \frac{1}{3}t - \frac{2}{3}p_1 + \frac{1}{3}p_2 + \frac{10}{3}$$
$$x_2 = \frac{1}{3}p_1 - \frac{2}{3}t - \frac{2}{3}p_2 + \frac{10}{3}$$

Substituting these outputs in 5 and maximizing with relation to p_1, p_2, we obtain

$$p_1 = \frac{2}{15}t + \frac{58}{15}$$
$$p_2 = \frac{52}{15} - \frac{7}{15}t$$

3.4   Case (F, F, H)

The profit function of the downstream firm is

$$\pi_d = Y - (p_1 + t)\, x_1 - (p_2 + t)\, x_2$$

where Y is given by 1. The profit functions of the upstream firms are

$$\pi_1 = (p_1 - w_f)\, x_1 \qquad (7)$$
$$\pi_2 = (p_2 - w_f)\, x_2$$

Maximizing π_d with relation to x_1, x_2, we obtain the demand functions of the inputs by the downstream firm (bearing in mind 3):

$$x_1 = \frac{1}{3}p_2 - \frac{2}{3}p_1 - \frac{1}{3}t + \frac{10}{3}$$
$$x_2 = \frac{1}{3}p_1 - \frac{1}{3}t - \frac{2}{3}p_2 + \frac{10}{3}$$

Substituting these outputs in 7 and maximizing with relation to p_1, p_2, we obtain

$$p_1 = \frac{10}{3} - \frac{1}{3}t$$
$$p_2 = \frac{10}{3} - \frac{1}{3}t$$

3.5 Case (H, H, F)

The profit function of the downstream firm is

$$\pi_d = (1 - \tau) Y - (p_1 + t) x_1 - (p_2 + t) x_2$$

where Y is given by 1. The profit functions of the upstream firms are

$$
\begin{aligned}
\pi_1 &= (p_1 - w_h) x_1 & (8) \\
\pi_2 &= (p_2 - w_h) x_2
\end{aligned}
$$

Maximizing π_d with relation to x_1, x_2, we obtain the demand functions of the inputs by the downstream firm (bearing in mind 3):

$$
\begin{aligned}
x_1 &= \frac{1}{3\tau - 3} (t + 10\tau + 2p_1 - p_2 - 10) \\
x_2 &= \frac{1}{3\tau - 3} (t + 10\tau - p_1 + 2p_2 - 10)
\end{aligned}
$$

Substituting these outputs in 7 and maximizing with relation to p_1, p_2, we obtain

$$
\begin{aligned}
p_1 &= 4 - \frac{10}{3}\tau - \frac{1}{3}t \\
p_2 &= 4 - \frac{10}{3}\tau - \frac{1}{3}t
\end{aligned}
$$

3.6 Case (F, H, F)

The profit function of the downstream firm is

$$\pi_d = (1 - \tau) Y - p_1 x_1 - (p_2 + t) x_2$$

where Y is given by 1. The profit functions of the upstream firms are

$$
\begin{aligned}
\pi_1 &= (p_1 - w_f) x_1 & (9) \\
\pi_2 &= (p_2 - w_h) x_2
\end{aligned}
$$

Maximizing π_d with relation to x_1, x_2, we obtain the demand functions of the inputs by the downstream firm (bearing in mind 3):

$$x_1 = \frac{1}{3\tau - 3}\left(10\tau - t + 2p_1 - p_2 - 10\right)$$

$$x_2 = \frac{1}{3\tau - 3}\left(2t + 10\tau - p_1 + 2p_2 - 10\right)$$

Substituting these outputs in 9 and maximizing in relation to p_1, p_2, we obtain:

$$p_1 = \frac{2}{15}t - \frac{10}{3}\tau + \frac{52}{15}$$

$$p_2 = \frac{58}{15} - \frac{10}{3}\tau - \frac{7}{15}t$$

3.7   Case (H, F, F)

The profit function of the downstream firm is

$$\pi_d = (1 - \tau)\, Y - (p_1 + t)\, x_1 - p_2 x_2$$

where Y is given by 1. The profit functions of the upstream firms are:

$$\pi_1 = (p_1 - w_h)\, x_1 \tag{10}$$

$$\pi_2 = (p_2 - w_f)\, x_2$$

Maximizing π_d with relation to x_1, x_2 we obtain the demand functions of the inputs by the downstream firm (bearing in mind 3)

$$x_1 = \frac{1}{3\tau - 3}\left(2t + 10\tau + 2p_1 - p_2 - 10\right)$$

$$x_2 = \frac{1}{3\tau - 3}\left(10\tau - t_1 - p_1 + 2p_2 - 10\right)$$

Substituting these outputs in 10 and maximizing in relation to p_1, p_2 we obtain:

$$p_1 = \frac{58}{15} - \frac{10}{3}\tau - \frac{7}{15}$$

$$p_2 = \frac{2}{15}t - \frac{10}{3}\tau + \frac{52}{15}$$

3.8 Case (F, F, F)

The profit function of the downstream function is

$$\pi_d = (1 - \tau) Y - p_1 x_1 - p_2 x_2$$

where Y is given by 1. The profit functions of the upstream firms are

$$
\begin{align}
\pi_1 &= (p_1 - w_f) x_1 \tag{11}\\
\pi_2 &= (p_2 - w_f) x_2
\end{align}
$$

Maximizing the downstream profit function with relation to x_1, x_2, we obtain the demand functions of the inputs:

$$
\begin{align}
x_1 &= \frac{1}{3\tau - 3} (10\tau + 2p_1 - p_2 - 10)\\
x_2 &= \frac{1}{3\tau - 3} (10\tau - p_1 + 2p_2 - 10)
\end{align}
$$

Substituting these in 11 and maximizing in relation to p_1, p_2, we obtain the prices

$$
\begin{align}
p_1 &= \frac{10}{3} - \frac{10}{3}\tau\\
p_2 &= \frac{10}{3} - \frac{10}{3}\tau
\end{align}
$$

3.9 Profits in the first stage game

Plugging x_1, x_2, p_1, p_2 in the profit functions, bearing in mind the production function 1., we can write the profits in the first stage game.

Case (H, H, H)

$$
\begin{align}
\pi_d &= 12\\
\pi_1 &= 6\\
\pi_2 &= 6
\end{align}
$$

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Case (F, H, H)

$$\pi_d = \frac{4}{675}\left(13t^2 - 251t + 2263\right)$$

$$\pi_1 = \frac{2}{675}\left(7t - 52\right)^2$$

$$\pi_2 = \frac{2}{675}\left(2t + 43\right)^2$$

Case (H, F, H)

$$\pi_d = \frac{4}{675}\left(13t^2 - 251t + 2263\right)$$

$$\pi_1 = \frac{2}{675}\left(2t + 43\right)^2$$

$$\pi_2 = \frac{2}{675}\left(7t - 52\right)$$

Case (F, F, H)

$$\pi_d = \frac{4}{27}\left(t - 10\right)^2$$

$$\pi_1 = \frac{2}{27}\left(t - 10\right)^2$$

$$\pi_2 = \frac{2}{27}\left(t - 10\right)^2$$

Case (H, H, F)

$$\pi_d = \left(-\frac{4}{27}\right)\left(\tau - 1\right)^{-1}\left(t + 10\tau - 9\right)^2$$

$$\pi_1 = \left(-\frac{2}{27}\right)\left(\tau - 1\right)^{-1}\left(t + 10\tau - 9\right)^2$$

$$\pi_2 = \left(-\frac{2}{27}\right)\left(\tau - 1\right)^{-1}\left(t + 10\tau - 9\right)^2$$

Case (F, H, F)

$$\pi_d = \left(-\frac{4}{675}\right)\left(\tau - 1\right)^{-1}\left(250t\tau - 4750\tau - 224t + 13t^2 + 2500\tau^2 + 2263\right)$$

$$\pi_1 = \left(-\frac{8}{675}\right)\left(\tau - 1\right)^{-1}\left(t - 25\tau + 26\right)^2$$

$$\pi_2 = \left(-\frac{2}{675}\right)\left(\tau - 1\right)^{-1}\left(7t - 50\tau - 43\right)^2$$

Case (H, F, F)

$$
\begin{aligned}
\pi_d &= \left(-\frac{4}{675}\right)(\tau - 1)^{-1}\left(250t\tau - 4750\tau - 224t + 13t^2 + 2500\tau^2 + 2263\right) \\
\pi_1 &= \left(-\frac{2}{675}\right)(\tau - 1)^{-1}\left(7t + 50\tau - 43\right)^2 \\
\pi_2 &= \left(-\frac{8}{675}\right)(\tau - 1)^{-1}\left(t - 25\tau + 26\right)^2
\end{aligned}
$$

Case (F, F, F)

$$
\begin{aligned}
\pi_d &= \left(-\frac{400}{27}\right)(\tau - 1) \\
\pi_1 &= \pi_2 = \left(-\frac{200}{27}\right)(\tau - 1)
\end{aligned}
$$

4 Solving the location game

We consider first the truncated 2×2 symmetric game where the downstream firm locates in country H. In order to assess the candidates of a locational equilibrium, we calculate a_1 and a_2, where

$$
\begin{aligned}
a_1 &= \pi_1(H, H, H) - \pi_1(F, H, H) \qquad &(12) \\
&= \left(-\frac{14}{675}\right)(t - 1)(7t - 97) \\
a_2 &= \pi_1(F, F, H) - \pi_1(H, F, H) \\
&= \frac{14}{225}(t - 1)(t - 31)
\end{aligned}
$$

It is clear from 12 that:

$$
\begin{cases}
a_1 < 0 \wedge a_2 > 0 & \text{if } t < 1 & F \text{ is a dominant strategy} \\
a_1 > 0 \wedge a_2 < 0 & \text{if } 1 < t < \frac{97}{7} & H \text{ is a dominant strategy} \\
a_1 < 0 \wedge a_2 < 0 & \text{if } \frac{97}{3} < t < 31 & \begin{array}{c} \text{There are two asymmetric Nash equilibria } (H, F) \\ \text{and } (F, H) \end{array}
\end{cases}
$$

We deal now with the truncated 2×2 symmetric game where the downstream firm locates in

F. Again we compute a_1 and a_2 such that

$$a_1 = \pi_1(H,H,F) - \pi_1(F,H,F) \tag{13}$$

$$= \left(-\frac{14}{675}\right)(\tau-1)^{-1}(3t+100\tau-97)(t+1)$$

$$a_2 = \pi_1(F,F,F) - \pi_1(H,F,F)$$

$$= \frac{14}{675}(\tau-1)^{-1}(7t+100\tau-93)(t+1)$$

It is clear from 13 that $a_1 < 0 \wedge a_2 > 0$ for all t, so that F is a dominant strategy. Hence the candidates to equilibrium in the game with three players are:

$$\begin{cases} (F,F,H) & if\ t<1 \\ (H,H,H) & if\ t>1 \\ (F,F,F) & for\ all\ t \end{cases}$$

We check now whether these profiles of strategies are indeed Nash equilibria in the location game, i.e., whether they are robust to deviations by the downstream firm. The no-deviation conditions are:

$$\pi_d(F,F,H) > \pi_d(F,F,F) \Leftrightarrow t < 10 - 10\sqrt{1-\tau} \tag{14}$$

$$\pi_d(F,F,F) > \pi_d(F,F,H) \Leftrightarrow t > 10 - 10\sqrt{1-\tau}$$

$$\pi_d(H,H,H) > \pi_d(H,H,F) \Leftrightarrow t > -10\tau - 9\sqrt{1-\tau} + 9$$

The last condition in 14 is always met since $-10\tau - 9\sqrt{1-\tau} + 9$ is negative for $\tau \in [0,1]$. A sufficient condition so that the output of the downstream firm is non-negative is

$$x_2(F,H,F) \geq 0 \Leftrightarrow t \leq \frac{43}{7} - \frac{50}{7}\tau \tag{15}$$

In Figure 1, we plot in (τ, t) space the following expressions:

$$t = 10 - 10\sqrt{1-\tau}$$
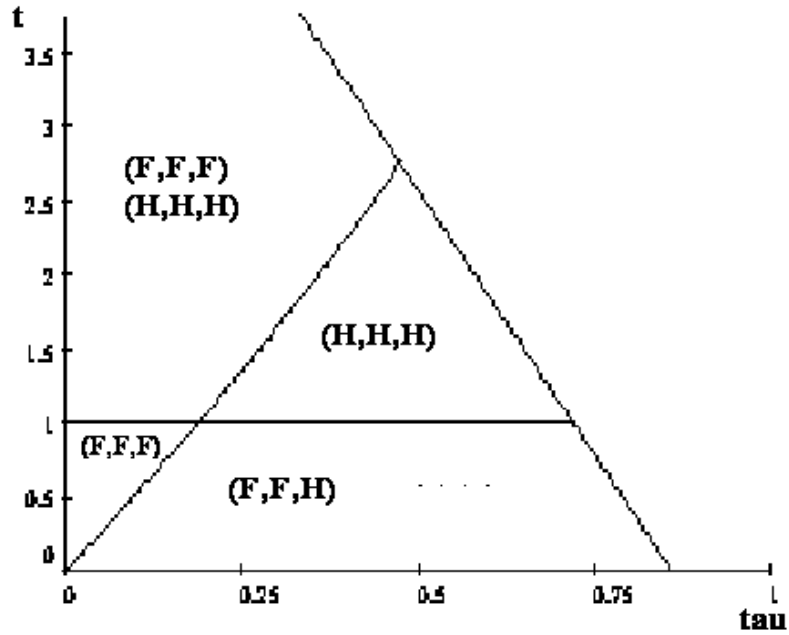
$$t = 1$$

$$t = \frac{43}{7} - \frac{50}{7}\tau$$

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Figure 1: Location regions in (τ, t) space.

5 Concluding remarks

Figure 1 shows that all location equilibria entail the agglomeration of both upstream firms in the same country. This follows from the fact that the market for the final good is located in a single region. Agglomeration of all firms occurs in country F if both transport costs, t and τ, are low, so that locations are driven by labor cost considerations only, apart from considerations related with access to market. By contrast, agglomeration takes place in region H if τ is high and t is medium. In this case, location of all firms is driven towards the location of the market for the consumer good.

Two special cases are of interest. The first one entails spatial fragmentation, the downstream firm being located close to the consumer good market in H while the upstream firms locate in the low labor cost country F. Unsurprisingly, fragmentation arises if t is low and τ is medium to high. The second case entails multiple location equilibria, with all firms either choosing to settle

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in country H or in country F. This case arises if the transport cost of the inputs is high, so that every cluster of locations is an equilibrium.

Hence, we can conclude that the location of vertically-linked firms is completely determined by the transport costs of the inputs and of the final good. We hope that this result, that was reached through a numeric simulation, can generalized to a wider setting.

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