Location Decisions in a Natural Resource Model of Spatial Competition

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1 - Introduction

- This work deals with the two-stage location-quantity game, in the linear city of Hotelling.

- Our main contribution is the introduction of an input resource, necessary for the production of the good that will be sold to consumers.

- Our main focus is on finding what are the consequences for firms' equilibrium locations given the introduction of this input.

2 – Theoretical Background

- Our work is built on the framework of Hamilton et al. (1989) and Anderson and Neven (1991).
  - We consider that firms compete in the Cournot spatial competition setting.
  - In this setting, which differs from the original price competition framework of Hotelling (1929), the main assumptions are:
  - Consumers are uniformly distributed in a linear city
  - In each point there is a market with inverse demand given by P=A-b.Q
  - Two firms compete in the market and have to transport their good to the markets if they are to sell any quantity. Transportation costs are linear with respect to the distance.
  - The dimension of each market point is big enough such that both firms sell in all points of the market.

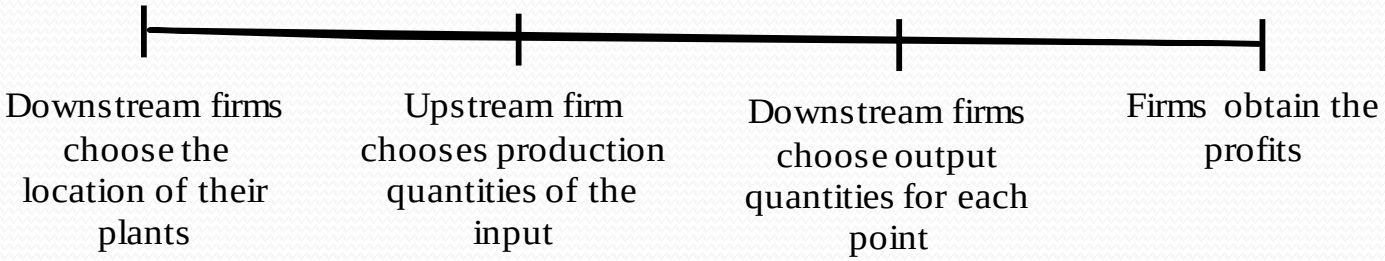
2 – Theoretical Background

- This spatial framework was extended in diverse ways:
  - Gupta et al. (1997) change the consumer density of firms throughout the city.
  - Mayer (2000) introduce location-dependent costs of production for firms.
  - Chamorro-Rivas (2000) and Benassi (2007) change the assumption of high reservation costs.
  - Shimizu (2002) introduces product differentiation (i.e. firms selling substitutes/complements/independent goods).
  - Pal and Sarkar (2002) introduce multi-store competition.

3 – The Model

- Our work introduces a natural resource input, which firms need to manufacture their good.
- We assume that the natural resource is located at the extreme of the market, and it is controlled by a monopolist.
- Downstream firms have to transport the input to their factory, and then have to transport the final good to every market point in order to sell it.
- As an example of businesses that could face similar problems:
  - Industries, which need to purchase the raw materials and then re-distribute the final good to the city or to other industries after manufacturing (e.g. furniture, steel).
  - Islands, in which the natural resources are dropped into a breaking point (usually, a port) which is controlled by an intermediary.

3 – The Model



- The key parameter is the unit input transportation cost:
  - We are interested in assessing how does the importance of the input influences the location choice of firms.
  - Other parameters, such as the dimension of each market point, the length of the city and the unit output transportation costs are fixed without loss of generality.

4.1 – Output Quantities Stage

- Firms have to decide which quantity to supply to each market point.
- Their profit in a given point is given by:

$$\prod_{i,x} = (10 - q_{i,x} - q_{j,x} - I - (|x_i - x|) - tx_i) q_{i,x}$$

- With standard Cournot calculations, we obtain the optimal decision per point. Hence the optimal quantity schedule is:

$$q^*_{i,x} = \frac{|x_j - x|}{3} - 2\frac{|x_i - x|}{3} + \frac{10 - I - 2tx_i + tx_j}{3}$$

4.2 – Input Quantities Stage

- In order to decide what is the optimal quantity to offer, the upstream firm must know the total quantities offered by the firms.
  - These are obtained by summing up all the quantities provided in every market point.

$$Q_i = \int_0^{x_1} (q^*_{i,x})dx + \int_{x_1}^{x_2} (q^*_{i,x})dx + \int_{x_2}^{1} (q^*_{i,x})dx$$

- With the integral being separated to get rid of the absolute values that were in the quantity schedule.

4.2 – Input Quantities Stage

- The Upstream firm has then to maximize its profit, which is simply given by the quantities sold times the input price.
- With the total quantities purchased by both firms, we obtain the inverse demand of the upstream monopolist.

$$I = \frac{x_1 + x_2 - x_1^2 - x_2^2 - tx_1 - tx_2 - 3Q_u + 19}{2}$$

- Multiplying by the quantities sold, we get the profit of the upstream firm, which we maximize with respect to the upstream quantity, yielding:

$$Q_u^* = \frac{x_1 + x_2 - x_1^2 - x_2^2 - tx_1 - tx_2 + 19}{6}$$

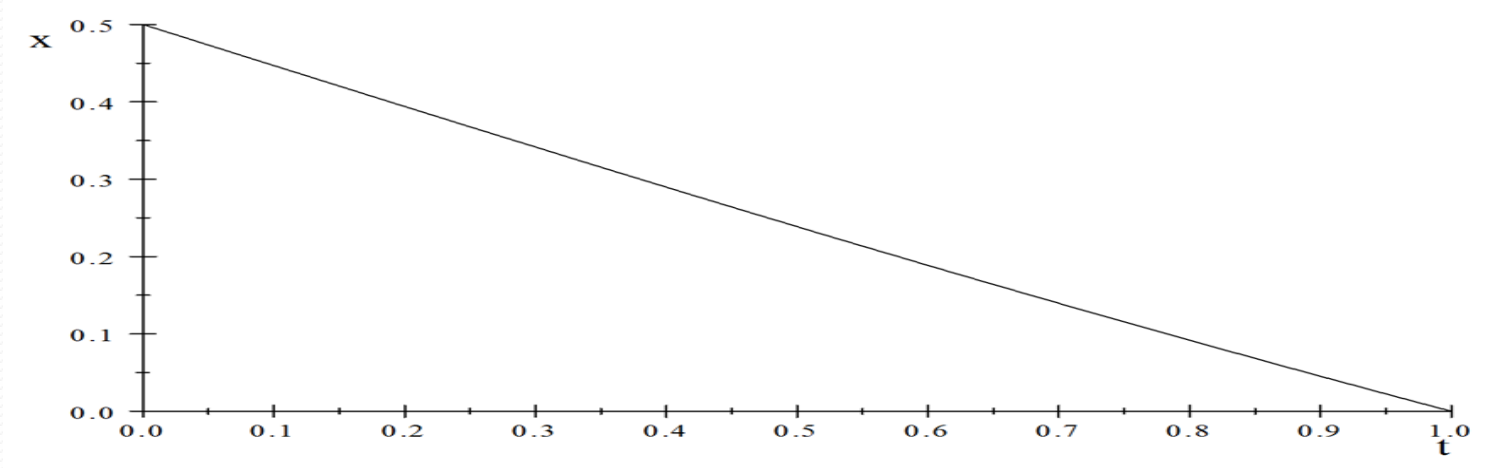
4.3 – Location Stage

- After replacing the input price and the optimal quantities we have obtained in the previous stage, we obtain the profit of the firms with respect to their location choices and the value of the unit input transportation cost.
- By differentiating the expression and equalizing the best-response functions of firms, we obtain the optimal location choice solely dependent on the input transportation cost, given by:

$$x_1 = x_2 = \frac{7t+9}{18} + \theta + \frac{91t^2 + 42t - 771}{\theta}$$

4.3 – Location Stage

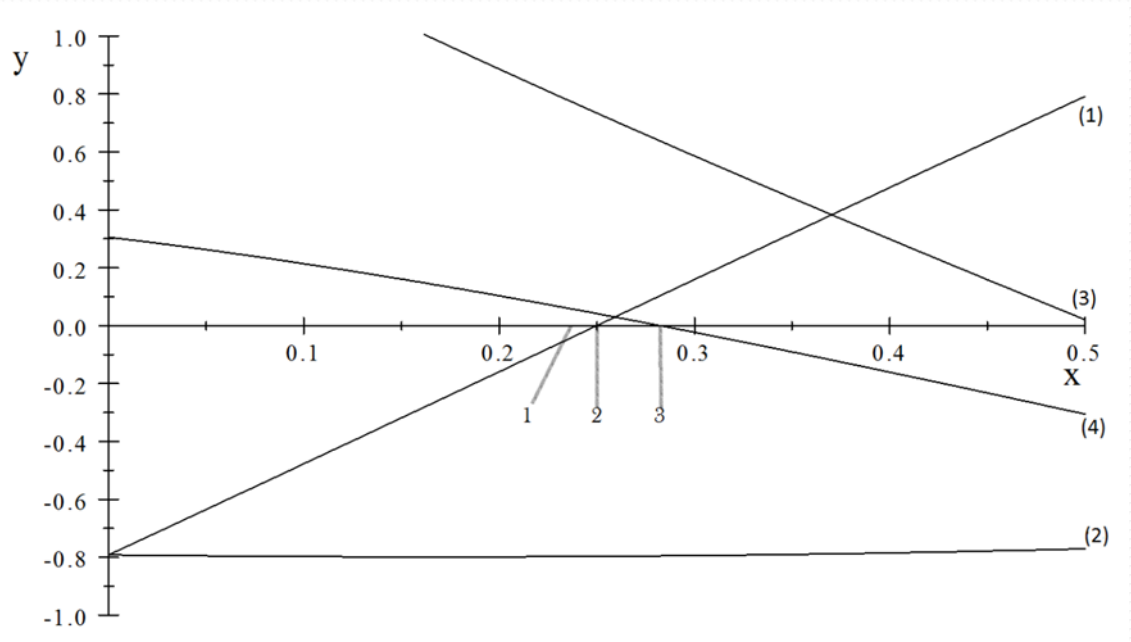
- We conclude that:
  - firms agglomerate independently of the value of the unit input transportation costs.
  - The optimal location of firms varies in a quasi-linear fashion with the value of u.i.t.c.



5 - Discussion

- To better understand the rationale behind firms' decision, we separate firm's profit between its 4 components:
  - 1 - Input purchasing cost; 2 – Input transportation cost; 3 – Output transportation cost; 4 – Revenues
- We fix t=0.5 as an example.
- We conclude that the input and output transportation costs are the main forces driving firms' movement in the line.

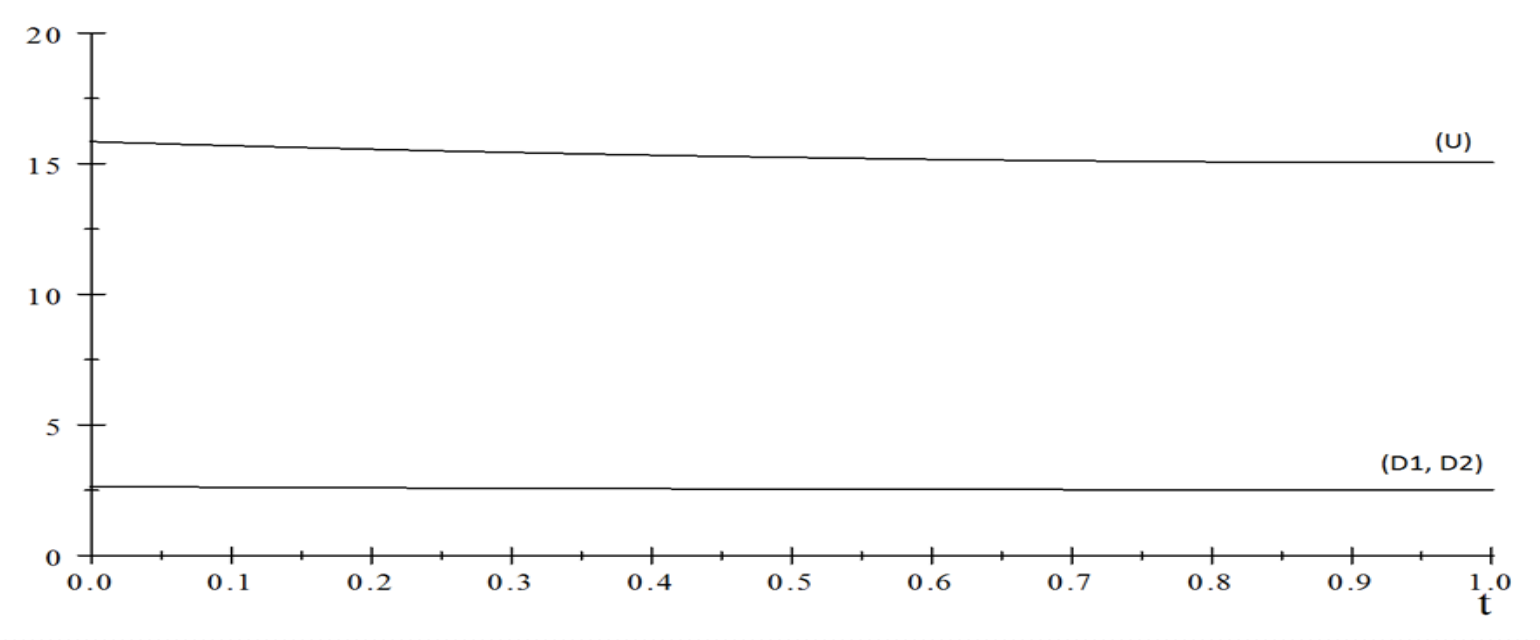
5 - Discussion



Derivative of the Profit Function with respect to the location variable

- 1 - Input purchasing cost; 2 – Input transportation cost; 3 – Output transportation cost; 4 – Revenues

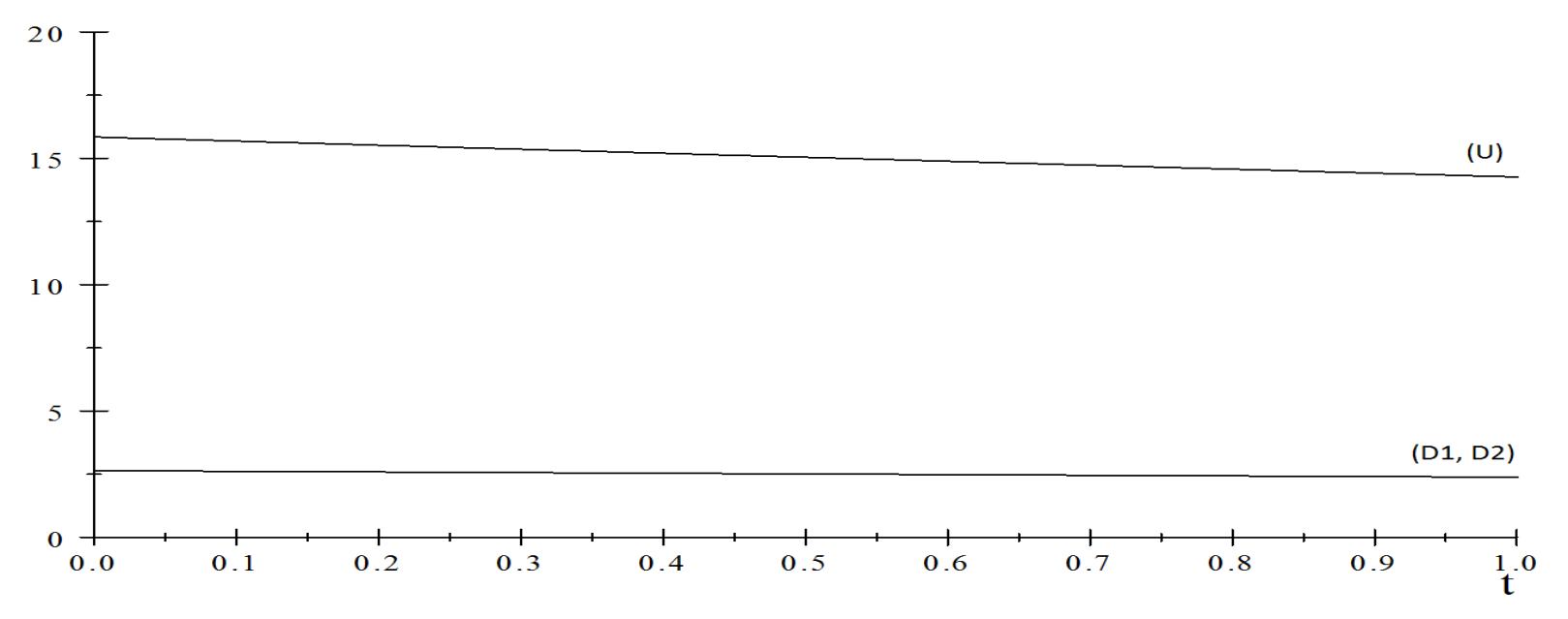
5 - Discussion



Profits of the three firms in the optimal path

- The main conclusion regarding profits in that these do not change much as input transportation costs become expensive.

5 - Discussion



Profits of the three firms when location is fixed

- This conclusion extends to the case where firms are not allowed to move after seeing changes in the u.i.t.c.

5 - Discussion

- Unit input transportation costs are crucial to determine what is the optimal location of the firms
- However, these transportation costs seem not so crucial to firms' profit results.
- Upstream firm profit decreases more than downstream firms, due to:
  - Their monopoly status
  - Not incurring in any transportation costs

6 – Social Planner

- We allow the possibility for a regulator to choose only the location of firms.
- The regulator seeks the maximization of the firms' profits plus consumer surplus.
- We arrive at the optimal location result, given by:

$$x_1 = x_2 = \frac{5t+3}{6} + \phi + \frac{35t^2 + 10t - 187}{36\phi}$$

- This solution is practically similar to the ones chosen by firms when competing.

6 – Social Planner

- Therefore, we conclude there is no need for a social planner intervention in the location stage.
  - A solution also found in Anderson and Neven (1991).

- The reason is that the competition between firms is too weak in the quantity framework
  - Therefore, both firms and social planner focus on the minimization of transportation costs, which ends up benefiting the upstream firm and the consumers as well

7 – Main Conclusions

- Firms agglomerate whatever the value of the u.i.t.c
- Firms move closer to the natural resource as the cost to transport it becomes higher, until the u.i.t.c. becomes equal to the u.o.t.c.
- A social planner would trust on private initiative in terms of location setting.
- U.i.t.c does not seem an important variable in firms' profits, in spite of firms being very responsive towards it.

8 – Future Research

- We think that further developments in this literature should be done about vertical relationships.
  - Topics such as integration, foreclosure and a better understanding on how input markets with a spatial component work could be developed, and seem to be missing in the literature.
  - All of these assumptions should be coupled with a focus on what would be the optimal location choice of both upstream and downstream firms in these situations.

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