THE LOCATIONAL IMPLICATIONS OF MANAGEMENT AND PRODUCTION FRAGMENTATION

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Abstract: The main objective of this work is to show that (1) communication costs within the firm and (2) managerial structures affect both the production fragmentation process and the economic specialization of cities. More specifically, as either communication costs diminish or managerial structures become more flexible, manufacturing plants tend to move from the large to medium-sized cities, while headquarters and business services tend to agglomerate in the metropolitan area. Analyzing the internal organization of firms, the present paper adds new dimensions (management and communication costs) to the fragmentation process that have been ignored by the literature.

Key words: Production fragmentation, management, business location, and organization of firms.
JEL: D20, R12

1. Introduction

Simon (1991) imagines a mythical visitor from Mars who "approaches the Earth from space, equipped with a telescope that reveals social structures" (p.27). The firms are shown as solid green areas, market transactions are red lines connecting firms, whereas pale blue lines represent the lines of authority connecting bosses with subordinates. Simon says that no matter which economy our visitor approached, the green areas would be the dominant feature of the landscape. With his story, Simon highlighted the importance of the organization of firms in this social structure called a market economy.

However, if our visitor compared the image captured by his telescope with the one taken by the first expedition 30 years earlier, he would be able to see important differences between both pictures. In the recent image, not only are there more red lines – some extremely long – that would show him the increase in the trade of inputs, but also many blue lines now connect discontinuous green areas as indirect consequences of the increasing intra-firm trade. This structural transformation has generated significant impacts on the global economy with effects at

different scales, national, regional, and urban, since the growing efficiency in transportation and communication has given firms more flexibility to make their location decisions.

In this paper, an attempt will be made to link the notions of fragmentation of production introduced by Jones and Kierzkowski (2005) with the model of authority n organizations proposed by Aghion and Tirole (1997). The paper is organized as follows; in the next section, a review of the relevant literature will be provided leading to the presentation of the model in section 3. The results occupy section 4 and a concluding section completes the paper.

2. Literature Review

The change in the trade structures of economies has been interpreted in several ways. For example, Hewings *et al* (1998) and, more recently, Guo *et al*. (2005) used Chicago data and obtained similar results to those found by Okazaki (1989) for the Japanese economy; the manufacturing sectors of big cities have become less and less dependent on local suppliers and demanders for physical goods, thereby increasing the interregional trade in inputs, whereas they have become more dependent on services produced within the metropolitan areas. This process, that has lowered the volume of input trade within a region, has been termed "hollowing out."

The "fragmentation" of the production process, in contrast, has been studied by Jones (2000) and Jones and Kierzkowski (1990, 2003, 2005) among others. According to Jones (2000), "production processes that have traditionally been vertically connected, so that all activity takes place in one location, are now frequently broken up or fragmented so that regions that are especially well suited to the production of parts of the process can now be utilized in producing these fragments" (p. 115).

To explain this production fragmentation, the authors propose an alternative framework where the service sectors play a crucial role, specifically, "increasing returns are assumed to reside in service link activities (including transportation) instead of on the factory floor (within production blocks)" (p.5). They call it an *alternative* framework in order to provide a benchmark comparison with the one proposed by Krugman (1991) among others in the construction of the ideas known today as the new trade theory based on existence of increasing returns in manufacturing sectors, monopolistic competition, and love for variety.

In the Jones and Kierzkowski framework, the process finds its realization between countries in which each economy produces only part of the final good thus increasing the international trade

of inputs (for a complementary perspective, referred to an vertical integration of production, see Hummels *et al*., 1998). However, as mentioned above, the hollowing out process, which has been shown to be strongly connected to the fragmentation of production, has been identified at the regional scale (Hewings *et al.*. 1998 and Okazaki 1989). The same tack has been taken by Krugman's ideas over the last twenty years: the new trade theory when applied to regional issues has offered insights on the importance of the spatial dimension in economic theory (Krugman 1991).

Two recent studies by Duranton and Puga (2002, 2004) not only help us to understand the relationship between features of the economic sectors and agglomeration process but also explicitly mention the connection between the organization of firms and the urban structure. Duranton and Puga (2002) present first some stylized facts about cities supported by empirical work. Then, they combine different assumptions about returns to scale, transportation costs, externalities, etc, and show the results in terms of city size and specialization/diversification of the city economies for each combination proposed.

The fifth stylized fact presented says that "Cities are increasingly specialized by function." According to them, "headquarters tend to co-locate with business services and have also become overwhelmingly concentrated in larger cities. At the same time, small and medium-sized cities remain quite specialized in particular manufacturing sectors" (p.159). Motivated by the stylized fact mentioned above, they assume that "final good production requires both a production plant and a headquarters" (p.169), which utilize non-tradable differentiated business services. As a result, they conclude that "when the additional costs associated with managing production remotely fall below a certain level, both the organization of firm and the urban structure undergo profound changes. Firms previously organized as single units become multi-unit organizations" (p.170). In this case, following their explanation, the headquarters of all sectors will agglomerate in larger cities where the business services are abundant, whereas the manufacturing plants will be located in cities with a greater same-sector specialization in final production. The specialization of the manufacturing cities comes from the fact that they assume the existence of own-sector externalities.

Duranton and Puga (2004) offer an insightful explanation for the fact that some urban areas have become functionally specialized instead of having their activities concentrated on a small number of sectors. This transition, they say, "is inextricably interrelated with changes in firm's

organization" (p.1). However, we cannot see in Duranton and Puga's model any connection between the agglomeration of business services and the efficiency of communication among or within firms. Renegotiations and flows of information are not considered; instead, their model emphasizes transportation costs. Therefore, even though the authors acknowledge the importance of the organization of firms, they do not model its internal structure; rather they assume a parameter for the cost for managing production remotely and firms are still seen as maximizing black-boxes.

There is no doubt that the "external-to-the-firm" reasons, such as the cost of factors and transport, are very important for firms' decisions. However, the relevance of the "external-to-the-firm" reasons does not mean that we should disregard the implications of spatially fragmenting the production on the transactions within the firms (across establishments) and how the boundaries of the corporations are determined. Spatial fragmentation is not only a matter of transport costs, but also it has to do with the control over production, whereas ownership structure may modify the decision about ex-ante investments given the risk of facing hold-up[1] problems.

Thus, models that can provide us with analyses about the internal organization of firms should be taken as complementary tools to examine the regional fragmentation of production and the hollowing out process. To do that, firms can no longer be considered as a maximizing black box. For example, Kreps (2002) notes that firms are frequently modeled as entities devoted to the "single-minded pursuit of maximal profit" (p. 592). However, he warns that when the problems studied have to do with the boundaries of or transactions within firms, this conception of a maximizing firm is anything but acceptable.

The main argument of the present paper is that the questions related to the fragmentation and hollowing out processes have much to do with both the firms' boundaries and the transactions within them. To explore this, we could consider the production process as a sequence of steps where each one makes only a part of the final good. All steps can be located either in a single place or in several locations and, besides, they may happen either inside a single corporation or

[1] Hold-up problems can arise in any relationship between two firms where ex-ante investment from one firm is required. The reason is that the ex-ante investment made by one firm increases the bargaining power of the other firm. Suppose that, after the first move – the ex-ante investment made by Firm A, Firm B may not consider the cost Firm A undertook to invest and, then, Firm B proposes to split 50:50 the revenue, appropriating the bulk of the surplus. Firm A, then, has no alternative but to agree, since Firm A does not want to lose the initial investment entirely. The risk of having this problem can lead firms to inefficient solutions.

can belong to different companies. In this scenario, the fragmentation and hollowing out processes can be seen as results of the firms' decisions about location and ownership structure of those sequences of the stages of production.

Regardless of the ownership structure, whenever stages *n* and *n+1* are located far away from each other, we have higher cost of transportation and communication. While traders will pay more for transporting, they have an alternative strategy to avoid increasing communication costs: the *n+1* stage can lower the level of control that it has over *n*-stage production. Therefore, how important communication is for a given production process and how communication flow goes through the different levels of a firm are questions that should be answered in order to fully understand firms' location decisions.

We can find helpful guidance in some recent work that seeks to model and explain intra-firm trade. The trade within firms happens whenever inputs and the final goods are produced by the same firm, but in different locations (countries). It has become increasingly important over the last decades and today it is responsible for about one third of international trade (Antras 2003).

Hence, as in the case of regional fragmentation, choices of location and ownership structure are key decisions made by firms that determine their arrangements in terms of whether or not the production should be spread in more than one place and whether they should either contract with a supplier or internalize the production. Antràs (2003), Antras and Helpman (2004), and Grossman and Helpman (2004) among others deal with this issue taking into account the risk introduced by ex-ante investments and the incompleteness of the contracts. Therefore, they investigate more deeply the specific features of the transactions within firms and between firms.

In the intra-firm trade model associated with Grossman and Helpman (2004), the principal decides the incentives that will be given to the agent (manager or entrepreneur). The success of the project depends on the agent's effort. The principal's maximization is subject to a participation constraint of the agent. Under an arms-length arrangement, the principal pays a fixed amount regardless of the success of the project and an additional quantity as a reward in the case the agent is able to provide the input required. The agent pays the fixed cost. Under vertical integration, the only differences are: (1) the principal can partially monitor the effort made by the agent and (2) the former pays for the fixed cost of the project.

In this two-region model, headquarters are placed in the North. The fixed cost is higher in the North than in the South. Moreover, the minimum amount (participation constraint) demanded by

the agent is higher in the North as well. Finally, the fraction of tasks that can be monitored by the principal is higher if the agent is located in the North. As they point out, there is no advantage for undertaking local outsourcing in their model. The model is based on alternative schemes of incentives and differences in prices (wages and fixed costs). The only uncertainty comes from the function that links effort and probability of producing proper inputs. After the revelation about whether or not the project succeeded, there is no dispute for any decision. Therefore, the residual right does not seem to be in the model.

Antras and Helpman (2004) construct a much more complex model where the production of final goods is a (Cobb-Douglas) function of headquarters services and intermediate inputs. There is a parameter for productivity that varies across firms. The principal has to find a producer of input and, then, both produce their specialization separately. After that, they bargain to split the surplus. The distribution of the surplus is sensitive to the mode of organization; in an outsourcing system, a failure to reach an agreement leaves principal and agent with no income, whereas in the case of vertical integration, the final good producer loses only part of the potential revenue.

Regarding location, the authors distinguish the North and the South by establishing three main assumptions. First, under vertical integration, the loss of not having reached an agreement is higher when inputs are produced in the South.[2] Secondly, the wage in the South is lower than in the North. The third difference is that the fixed cost of a manufacturing plant is higher in the South.[3]

Antras (2003) emphasizes the capital intensity of the sectors and it constitutes a key variable to determine the best arrangement. As a result, the author finds that "the attractiveness of integration (…) increases with the capital intensity of intermediate input production" (p.20). The idea of his model is to combine a framework of organization of firms based on Grossman and Hart (1986) and Hart and Moore (1990) with Helpman and Krugman (1985) which incorporates imperfect competition and product differentiation. Thus, the general equilibrium model constructed in Antras (2003) allows him to amplify the results for a single firm and to predict the pattern of trade; the volume of intra-firm imports is an increasing function of the capital-labor

[2] According to them, "More figuratively, we think of this assumption as reflecting less corruption and better legal protection in the North".

[3] They justify this point saying that "the fixed cost of search, monitoring, and communication are significantly higher in the foreign country".

ratio of the importing country. Moreover, it is also an increasing function of the size of both countries involved in trade. Finally, Antras uses the data available from the Bureau of Economic Analysis (BEA) to test the results of his model.

There are some important papers on incomplete contracting that model the relationship between two parties under possibly unpredictable circumstances. Grossman and Hart (1986) present the concept of residual right which is the right to decide under circumstances not predicted by the contract. The authors show that the ownership of the assets (and consequently the residual right) should be given to the party that invests more in order to reduce her uncertainty and minimize the distortion of investment.

Holmstrom and Milgrom (1994) model an organizational structure of incentives, pointing out the interrelation among incentives, ownership of assets, and worker freedom; claiming that the strategy of the owner should consider all aspects jointly. Aghion and Tirole (1997) capture the idea of residual rights by introducing a scheme of delegation of authority. In their model, the principal can delegate the decision (formal authority) to the agent. Nonetheless, since the individuals undertake some effort to learn about a project and they may learn nothing, the real authority (the final decision) may not belong to the party that has the formal authority. The model provides insights about how formal and real authorities interact with each other and analyzes facts that increase the real authority of the agent.

Before explaining the main difference between those papers on intra-firm trade and what will be presented here, it is worth mentioning two papers that endogenize the internalization of decisions of multinational firms, taking into account the information asymmetry present in the production process. Both models, Ethier (1986) and Ethier and Markusen (1996), focus on knowledge-based capital. In Ethier and Markusen (1996), firms decide between either costly exporting or producing abroad which means a loss of the value of its knowledge. Then, because of the cost of losing the exclusivity of knowledge, the direct investment turns out to be possible even between countries with similar endowments once it protects the firms' knowledge-based capital.

On one hand, the similarity between the previous studies on firms' decisions about location and ownership structure and the present paper is that in both cases the analyses address questions related to the incompleteness of contracts and its consequences such as the hold-up problem. Therefore, they all fill the theoretical gap that has been identified in work about business location decision-making and its effects in terms on urban system, agglomeration, and fragmentation

processes. Besides, they incorporate parameters that represent location advantages such as wage differentials between countries (in regional models we might focus on distance between production and either inputs or markets, but in any case we will still have locational advantages). On the other hand, given their aims, the international trade literature has no reason to emphasize the relationship among sectors and, particularly, the role played by service sectors (service links in Jones-Kierzkowski's approach or business services in Duranton-Puga's approach); which turn out to be crucial points when the urban system and the regional production process are the objects of study. Moreover, communication and decision process within firms are not considered.

The main objective of this paper is to show that communication costs and managerial structure affect both the production fragmentation process and the economic specialization of cities. More specifically, as communication costs diminish (or managerial structure becomes more flexible) manufacturing plants move from the big city to medium cities, whereas headquarters and business services tend to agglomerate in the metropolitan area.

3. Model and Simulation

The model proposed here is based in Aghion and Tirole (1997) that analyzes the interaction between a superior (principal) and a subordinate (agent) under a particular circumstance; they have ***n*** possible projects in hand and must decide which one will be undertaken. Both agent and principal will carry out some effort to learn about the project. Each one can learn either everything or nothing about it. The probability of understanding everything regarding the project is the amount of effort, which varies between zero and one. The principal can delegate the decision to the agent, thus, transferring the *formal* authority to the agent. Otherwise, the principal keeps the formal authority with her. It is important to understand in more detail what *formal* authority and *real* authority mean in this model.

The decision process can be seen as a game with (at most) four periods. In the first period, the principal decides who will have the formal authority. In the second period, each one decides her own level of effort that needs be made in order to learn about the projects and, then, they learn either everything or nothing. Next, after the learning process, the individual who has the formal authority that is defined in period 1 plays in the third period. Assume that player *X* has the formal authority. If player *X* has learnt everything in period 2, she chooses the project and the

decision is made (in this case, there will not be the fourth period). Otherwise, player *X* gives player *Y* the *real* authority, i.e., the right to choose the project. Thus, in the last period, player *Y* will not choose any project only if he or she has not learnt anything in period 2. In this case, the outcome will be zero for both players. If player *Y* knows everything about the projects, player *X* will rubber-stamp player *Y*'s decision.

In the present work, in order to enable the simulation to identify the effects of both managerial structures and communication costs on the production fragmentation process, geographic aspects and communication costs within the firm are introduced into the original model. Besides the delegation scheme and the level of effort, the owner[4] (principal) decides the location of the manufacturing plant and the headquarters (HQ). The choice of placing the manufacturing plant far away from the owner may bring advantages and disadvantages to the firm. The only sure advantage of having the manufacturing plant close to the owner has to do with the efficiency of communication between the owner that lives in the HQ and the controller (agent) that is located in the manufacturing plant. Therefore, in other words, the disadvantage of placing the plant far from the owner is that communication is less efficient or one could consider this to imply that the cost of implementing an efficient communication system is higher. The question, then, could be why should the manufacturing plant be located far away if this does not seem to be desirable for the owner? Some reasons can be advanced to explain why firms implement the multi-locational system such as factor prices, markets and the presence of business services. As a consequence of those reasons, manufacturing plants and headquarters may have the highest locational advantage in different places and, as a result, the owner has an incentive to spatially split the production process.

In Aghion and Tirole's (1997) model, the agent decides the effort based not only on the formal authority arrangement, but also on the effort expended by the principal. The model that will be presented here does not take the second aspect into account. The assumption behind this simplification is that the controller does not know how much effort the owner is carrying out. Thus, the utility function of the agent will not be considered in this model. Nonetheless, though the agent's maximization problem is not presented explicitly, it is assumed that she responds to the formal authority scheme defined. Instead of determining the amount of effort of the agents

[4] A distinction between the present model and the one constructed by Aghion and Tirole (1997) is that, now, the principal is the owner of the firm and the analyses will be focused on her utility function. Thus, the utility function of the principal is composed by the monetary return of the projects and the cost of effort carried out by her.

by solving their maximization problems, it will be exogenously determined for each formal authority scheme.[5]

There is a crucial aspect of the model that should be understood. The owner is seen as a receptor of information coming from the manufacturing plant. The owner learns from that information and, therefore, any problem of efficiency of communication will hurt her understanding. Moreover, the only effort involved in this communication is the owner's. The controller does not need any communication to learn about and evaluate the projects since the project is related to the manufacturing plant controlled by him *in loco*. Therefore, even when the controller and the owner are far from each other, the controller does not have any additional cost to learn about the project because the source of information is always close to him.[6] As a consequence, no effort on the part of the owner means there is no communication between her and the controller. In that case, the controller will have the real authority.

Equations (1) and (2) represent the utility function of the owner of firm *j*, when the manufacturing plant locates in city *mp* and the headquarters is in city *mh*. In equation (2), the formal authority is delegated to the controller. From the comparison between both, the owner decides if she will delegate the formal authority. The owner decides locations for the manufacturing plant and the headquarters.

Depending on owner's decision about the formal authority, her utility function can be represented as follows:[7]

$$u^j_{mp,mh} = E^j_{mp,mh}B + (1 - E^j_{mp,mh})e_n\alpha B + \sigma \ln(1 - tE^j_{mp,mh}) + w^j_{mp,mh} \quad (1)$$

$$u^j_{mp,mh} = (1 - e_d)E^j_{mp,mh}B + e_d\alpha B + \sigma \ln(1 - tE^j_{mp,mh}) + w^j_{mp,mh} \quad (2)$$

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[5] About the effort of the agent, Aghion and Tirole remark: "Delegation thus increases the agent's initiative; because the principal cannot overrule the agent, the agent has more incentives to become informed" (p.12). This interpretation is incorporated in the present model. The fact that effort of the controller (*e*) is not a function of the effort of the owner (*E*) can be understood as if the agent had an expectation about the effort of the owner under those two delegation schemes. Thus, the expectation of the owner's effort would be incorporated in the controller's maximization problem, instead of its actual value. Note that, in their model, *E* is lower when the agent has the formal authority; therefore, in this case, not only can the principal not overrule the agent, but also *E* is low. Both consequences of the delegation increase the agent's initiative and, consequently, *e*. In other words, including the effect of the actual effort of the owner on the agent's effort would only intensify the difference between e_d (under delegation) and e_n. Hence, assuming that $e_d > e_n$ seems to change neither the idea of the original model nor the main results of the present work.

[6] Although the owner needs information that comes from the manufacturing plant, there is no correlation between the learning processes of the owner and the controller. We can justify this fact by assuming that, first, both need objective information to learn but they interpret it by themselves, separately. Second, the owner can communicate to any worker and, thus, the controller cannot limit the owner's knowledge.

[7] $\boldsymbol{w}$ does not depend on $\boldsymbol{E}$ since it can be seen as, for example, the difference in controllers' wages.

$mp = mh \Leftrightarrow t = 1$
$mp \neq mh \Leftrightarrow t > 1$

E and *e* represent the principal and agent's efforts, respectively. The payoff of the principal is *B* when the best project is chosen according to her preferences and αB when the agent chooses the project. The third term of the right side, $\sigma \ln\left(1 - tE^{j}_{mp,mh}\right)$, measures the cost of effort made to understand the project. The marginal cost is zero when effort is zero and it is infinite when the effort is one.

Note that in equation (1), *EB* is the probability of identifying the best project multiplied by the payoff that this project yields to the principal. The effect of delegation on the principal's payoff can be seen in equation (2). *(1-e)* precedes *EB*, which means that the choice of the principal will be undertaken only if the agent does not learn anything. Otherwise, the agent will learn everything and choose the project, which is represented by the second term of the equation (2).

Finally, there is some divergence between the interests of the principal and the agent. If the principal chooses the project, her payoff is *B*, but when the agent makes the final decision, the principal's expected payoff will be a fraction of *B*. If the manufacturing plant is located far from the owner, part of the effort undertaken by the owner is lost in the process and, then, *t* is greater than one. Otherwise, *t* is equal to one and there is no loss of efficiency.

The locational advantage (*w*) is determined by three elements: (1) the amount of business services present in the city, (2) the population size,[8] and (3) the remaining exogenous terms (proximity to inputs, wage differential, etc). Thus, *w* turns to be:

$$w^{j}_{k,m} = p^{j}_{k} + h^{j}_{m} \tag{3}$$

where:

$$p^{j}_{k} = X^{j}_{k} + \delta_1 Pop_k \tag{4}$$

$$h^{j}_{m} = \delta_1 Pop_m + \delta_2 S_m \tag{5}$$

Therefore p^{j}_{k} is the locational advantage of placing the manufacturing plant of firm *j* in city *k* and h^{j}_{m} is the gain of locating the headquarters of firm *j* in city *m*.

[8] proxy for final demand and other types of services. Congestion costs are not considered.

X_k and Pop_k represent respectively the exogenous locational advantage for firm j and the population in city k, whereas S_m is the amount of business sector of city m. Therefore, population affects both h and p. A large population could mean a potential market for production, reducing the cost of transportation to ship the final good from the manufacturing plant to the consumers. In the case of the headquarters, the large populations of metropolitan areas would be desirable in terms of supplying skilled workers.

Finally:

$$Pop_m = \theta_1 NH_m + \theta_2 NP_m \quad (6)$$

$$S_m = \theta_3 NH_m \quad (7)$$

NH_m and NP_m are respectively the number of headquarters and manufacturing plants in city m. Note that the communication costs affect only the efficiency of communication within the firm. Therefore, the effect of communication costs on the relationship between manufacturing and business services is not considered. However, this simplification should not be seen as a serious limitation since the main objective here is to show how and why (1) communication costs *within* firms and (2) their managerial structures can change the production distribution over the region.

In the simulation, the number of cities and firms was arbitrarily defined as, 20 and 100, respectively. The only purpose of this choice was to use the simulation to reproduce what the model claims. The distance between any two cities is the same. Besides, in the first period, they have the same population size (normalized at zero) and no firms. Therefore, none of the cities has business services in period zero (see equation 7). Thus, for the first firm, the only variable that can make the total locational advantages (w) vary across cities is X. Then, at the beginning of the first period, the first firm appears. It analyzes the cities and chooses a location for the headquarters and also a place for the manufacturing plant. For the manufacturing plant, it will choose city k such that:

$X_k^1 \geq X_g^1$ for all $g \leq 100$.

In fact, for each firm, X will be positive in just one city and zero in any other location. The locational advantage is homogenously distributed across cities, i.e., given that there are 100 firms and 20 cities, each city will present positive locational advantage for 5 firms.

Since there are no business services in this economy yet and the populations across cities are the same, the headquarters of firm 1 will be located in the city where the plant is located (city k) in

order to avoid unnecessary costs of communications. Given this choice, before the second period starts, the simulation updates the population and the amount of services in city *k*. The size of population increases and the business service sector becomes positive. Now, the economy is ready to receive the second firm.

Suppose that city *v* is close to the input of firm 2 and, consequently, it has the highest value of X^2.

$$X_v^2 > X_k^2 \text{ for any } k \neq v$$

Therefore $p_k^2 < p_v^2$ and firm 2 will have 3 alternatives: (1) locate the manufacturing plant in city *v* and the HQ in city *k*; (2) locate everything in city *k*;[9] and (3) locate everything in city *v*. The last two options have no communication costs.[10]

After the decision of the second firm, a new updating occurs and the third firm appears. The important point is that the complexity of the decision-making does not increase as the number of firm increases. Firm *j* identifies the better places both for the manufacturing plant and for the HQ. Then, regardless of the number of firms already in place, firm *j* has no more than three options to be evaluated as was also the case for the second firm: agglomerating everything (no communication costs) where the manufacturing plant benefits most; agglomerating everything (no communication costs) where the HQ benefits most; or splitting the firm to take the locational advantages in both places.

To achieve Nash equilibrium, the simulation should not stop in the last firm's decision of the first round. Instead, the process would stop when the economy converged to an equilibrium, i.e., when the decisions made in round *z* were the same as those made in round *z*+1. If it is assumed that the sequence of entries is the one actually observed, some fixed costs have to be imposed from the second round on (see Pellenbarg *et al.*, 2002). Assuming that the cost of migration is large enough, the Nash Equilibrium turns out to be determined in the first round, as will be the case here. This assumption is justified by the fact that the main purpose of this paper is to show that different managerial structures and communication costs generate *different levels* of

[9] Even if $p_k^2 < p_v^2$, the firm will choose this alternative as long as the combination between no communication costs and presence of business services offset the advantage of placing the manufacturing plant in city *v*.

[10] If the owner is allowed to delegate the decision to the controller, she will have six options: the same three location choices under delegation and no-delegation.

agglomeration (or fragmentation). The analysis is comparative and the absolute values do not mean much.

Initially, all the cities are of the same size. The population of a given city is a function of the number of manufacturing plant and headquarters (HQ), whereas the amount of business services is a function only of the number of HQ located in there. Therefore, there is no maximization problem for service sectors and the only agent that makes decisions (location and delegation) is the manager of the manufacturing corporation.

At each period of time a new firm arrives. Hence the increase in the number of firms is what drives the simulation. At the beginning of period *t*, firm *j* decides the location of the headquarters and the manufacturing plant, taking into consideration the locational advantages and the cost of communication in case the corporation is split in two different cities.[11] Given this decision, population increases where the manufacturing plant and the HQs are located; whereas the amount of business services only rises where the HQs are placed.

Perhaps, the most important simplification assumed in this extension is related to the lack of a market definition. The analysis focuses on the production side and the mode of competition does not play any role in the firms' location decision. Including this important aspect could be one of the tasks for further research. Nonetheless, the justification provided by Jones and Kierzkowski (2005), who similarly do not emphasize the mode of competition in their studies about fragmentation, could be used as a supporting argument for the decision that emphasizes the production side: "(…) by ignoring the costs involved in reaching the final consumer, a central concern in the economic geography literature, we avoid the analytical complexities introduced by focusing on consumer demand for variety (…) Emphasizing that consumers have a taste for variety served extremely well the analysis of intra-industry trade in 'new trade theory,' but perhaps does not as easily pass a cost/benefit test in the 'new economic geography'" (p.4).

Before analyzing the results, it is important to highlight the differences between what has been proposed here and the analysis presented by Jones and Kierzkowski about the production fragmentation process; while they consider service links (management, communication costs, and transportation costs) as key activities that present increasing returns to scale, here the model is designed to focus the analysis only on management and communication costs within the firm.

[11] Here we have the same idea we had in the original model. The difference is that now the locational advantages are determined not only exogenously but also by both the amount of business services and the size of the population.

However, they do not model the organization of firms and hence neither the effects of different managerial structures nor the interaction between communication costs and management can be examined by their framework. Jones and Kierzkowski (2005) point out that "such a geographic separation of production fragments introduces the necessity of establishing service links in the form of transportation, communication, and other coordinating activities" (p.5). In their framework, firms face the trade-off between (1) fragmenting the production to exploit a location advantage (which decreases its marginal costs) and, doing so, they have to pay the costs of service links to coordinate the production now geographically dispersed and (2) producing everything in one location without additional costs in terms of service links, but with higher marginal production costs. As mentioned, the crucial assumption in their work is that the service links present increasing returns to scale. As a result, there is a tendency for fragmenting the process as the production increases once the costs of service links becomes less significant. Here, increasing returns are not necessary to explain the production fragmentation.

Nonetheless, the model does not aim to explain all the causes of this phenomenon, rather it presents a framework modeling the internal organization of firms, an aspect that has been overlooked by the literature on fragmentation, so that it can add some additional dimensions (management and communication costs) to the debate that have been ignored by the literature.

Finally, the Jones-Kierzkowski's framework allows them to identify the fragmentation process by examining a single firm, i.e., the number of production blocks (placed in different location) utilized by the firm indicates the degree of fragmentation of the production process. In contrast, in the present model, many firms can use only either one or two production blocks, once introducing multi-establishment firms would make the model much less treatable. Thus, the intensity of the production fragmentation is measured by the number of firms that split their production into two blocks. Despite the limitation of not allowing firms to split the production in many blocks, the advantage of what has been proposed here is that, as mentioned before, this framework can incorporate management aspects and communication costs into the urban system analysis.

4. Procedures and Results

The simulation deals with two scenarios: initially, the owner is allowed to delegate the formal authority to the controller, whereas, in the second part, the owner does not have this alternative.

Besides, as explained in detail below, different levels of communication cost are used to check its impact on the regional economy. It is worth emphasizing that the objective is to show how and why both the internal structure of the firm and communication costs can affect the distribution of production over a given region. The parameters used do not come from estimations; their role is to introduce into the simulation the assumptions made in the model construction. The results coming from the simulations do not aim to measure any specific effect.

$\sigma = 0.5 \quad B = 4 \quad X = 0.8$
$e_n = 0.3 \quad e_d = 0.7 \quad \alpha = 0.75$
$\delta_1 = 0.4 \quad \delta_2 = 2.2 \quad \theta_1 = 0.02$
$\theta_2 = 0.08 \quad \theta_3 = 0.08$

Recall that at time zero, the population and the amount of business services of all (twenty) cities are normalized to zero. Before the first firm comes, the simulation randomly defines the order of entries of the firms. Each firm (owner) decides four things: (1) the delegation scheme; (2) the location of the manufacturing plant; (3) the location of headquarters; and (4) the level of effort to learn about the project. In the first round, the cost of communication for firms having manufacturing plant and HQ in different locations is equal to one. It means that, in the first round, firms do not face additional communication costs when they decide to split their production. Then, the first result is obtained.

The simulation then moves to the second round: with the same order of enters, all firms make their decisions facing a higher communication cost. In the second round, it will be 1.1; in the third, it raises to 1.2, and so on. The communication costs vary between 1 and 2 in eleven rounds. Thus, it provides eleven results for eleven distinct cases.

The procedure described in the last two paragraphs is repeated 60 times, defining at random new orders of entries for each set of eleven rounds (60 orders of entries). Thus, for each level of communication cost, the simulation provides a sample of 60 maps of production as the final result. Therefore, this first part allows us to analyze the effect of different communication costs for the distribution of production and to check whether or not it affects the process of production fragmentation. The second part of the simulation follows the same idea using those 60 orders of entries defined in the first part. The only difference centers on the possibility of delegating the formal authority to the controller present in the first scenario: in the second part, the owner cannot delegate the final decision (this decision structure will be called “inflexible

management"). Thus, the outcome of the second can be compared with what was obtained in the first part when firms had "flexible management."

<<insert table 1 here>>

Table 1 shows the results for those two managerial structures and five levels of communication costs. The numbers represent the average (of those sixty simulations) of the concentration (%) of HQ and manufacturing plants in the biggest city of the region.[12] The first results to which attention should be drawn are the different tendencies presented by HQs and manufacturing plants. Under both managerial structures, as the communication costs reduce, *HQs concentrate in the main city of the region, whereas the manufacturing plants move to medium cities.* Therefore, when communication costs are low, the large city becomes (functionally) specialized in services. In contrast, the manufacturing plants that in the beginning are more concentrated in the metropolitan area, – are distributed across cities according to their own locational advantage. As consequence, one should expect that trade of manufactured good within the metropolitan area is more intense when communication costs are high.

The comparison between two scenarios, with flexible and inflexible management, shows the importance of the internal structure of firms for the map of production. The most important point is the fact that the percentage of manufacturing plants agglomerated in the large city is lower when firms have flexible management for any communication costs. The opposite happens when headquarters are analyzed. Therefore, the possibility of delegating the formal authority to the controller considerably increases both the fragmentation of production and the functional specialization of the metropolitan area (services). When the owner cannot delegate the formal authority to the controller and communication costs are high, the owner keeps the manufacturing plant and the HQ in the same city as can be seen in the three last columns.

In figures 1 and 2, the complete sequence of the averages of the concentration of HQ and manufacturing plants can be seen for different communication costs.

<<insert figures 1, 2 here>>

Essentially, the figures confirm what was seen in table 1. Nonetheless, note that, in the case that delegation is allowed, the concentration of manufacturing plant increases as communication

[12] Note that, differently from the so-called Core-Periphery model, which assume the existence of a big city surrounded by the periphery, in the present work the big city emerges from the model and the location where it will grow depends on the order of enters.

costs go from 1.3 to 1.2; this happens because the concentration of headquarters (figure 2) jumps when communication costs become 1.2, which attracts some manufacturing plants to the metropolitan area.

While the numbers and graphs presented above strongly suggest that both low communication costs and managerial flexibility contribute to the processes of production fragmentation and functional specialization of the metropolitan areas, the next step is to test if the averages found for the scenarios analyzed are statistically different. Since the averages of concentration of headquarters and manufacturing plants come from a simple of sixty simulations (greater than thirty), the following formula can be used:

$$z = \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \tag{8}$$

The results are summarized in Table 2 and 3.

<<insert tables 2 and 3 here>>

First, table 2 analyzes the effects of communication costs. It compares the average concentrations of establishments for different costs of communication (under flexible management). For instance, the number in the northwest cell (12.49) compares the concentration of HQs for communication costs 1.1 and 1.5. In contrast, table 3 compares the average concentrations of establishments for different managerial structures given the communication cost.

Whenever the values in tables 2 and 3 are greater than 1.65, the averages analyzed can be considered statistically different (with 5% of significance). The concentration of manufacturing plants (table 2, row 2) presents significant changes for different communication costs, which shows the importance of low internal communication costs for firms to decide spreading their production. Still in table 2, it can be verified that the concentration of headquarters does not change for high communication costs. However, the concentrations of HQs are very different for low costs. In table 3, except for the case of the concentration of HQs for very low communication costs, the results confirm that different managerial structures drive the regional economy to distinct maps of production.

5. Conclusions

The main limitation of this model is the assumption that migration costs are high enough to prevent firms from changing their location decision. Firms decide their best location and cannot move in response to the other firms' choices. Besides, they do not know the preferences of those firms that will locate in the future and, then, they make the decision taking into consideration only those firms that have already located. An interesting extension of the work would be to derive the Nash Equilibrium by assuming there is a finite cost of migration. In this case, it is important to introduce some centrifugal forces - such as congestion costs – as well.

The general conclusion of this paper is not very intuitive at first sight: the rapid development of communication tools, such as the internet that have occurred in the last decades has provided firms with new alternatives to benefit from their location decisions. When managers can coordinate the production from anywhere, and firms are not seen as maximizing black-boxes, what happens is that firms can take advantages by placing each establishment and department where they benefit most from immobile resources and markets.

This model also confirms the findings coming from empirical work such as Arita and McCann (2002) and Sheard (1983) about the positive relationship between decentralization of location and decentralization of decision. Arita and McCann (2002) analyze the electronics and semiconductor industry and attempt to link the internal structure of the American and Japanese firms with the location of their assembly plants. According to the authors (p. 360), "the Japanese organizational arrangements are constructed within a strict hierarchical system with very little individual autonomy, whereas US firms have a greater degree of decision-making latitude." Therefore, it may be seen that there is more delegation in the American structure than in the Japanese corporations. Assuming this to be the case, the model proposed here would expect that there would be a tendency for the Japanese plants to be located closer to headquarters, whereas American plants would be more aggressive in placing their plants where the locational advantage appears to be higher. In the authors' word: "(…) the US firms are much more spatially differentiated and internationally integrated than the Japanese firms, in the sense that the activities are distributed more widely according to both location and activity types" (p. 359).

It has been claimed and shown that decreasing communication costs have played an important role for the process of production fragmentation. More than that, the economy of the metropolitan area becomes more specialized in services as communication costs diminish. The

effects of communication costs cannot be understood (even analyzed) without incorporating into the framework the processes of learning, coordinating, and negotiating since the flow of information only affects the economy throughout interactions among agents. For this reason, the boundaries of the maximizing black-boxes have to be broken up and Aghion and Tirole (1997) offer an insightful model to do that. As result, the present model shows that managerial structure plays also a relevant role for both processes: fragmentation of production and specialization of the metropolitan area's economy.

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Table1: Concentration (%) of Headquarters (HQ) and Manufacturing Plants (MP) in the metropolitan area.

Management Structure	Communication Costs	1	1.1	1.5	1.9	2
Flexible Management	Concentration of HQ	100	95.3	85.5	85.5	85.5
	Variance	0	7	40.2	40.2	40.2
Flexible Management	Concentration of MP	10.3	35.6	50.3	58.3	58.3
	Variance	10.5	26.7	81	74.7	74.7
Inflexible Management	Concentration of HQ	100	95.3	67.3	67.3	67.3
	Variance	0	7	248.8	248.8	248.8
Inflexible Management	Concentration of MP	20.6	40.6	67.3	67.3	67.3
	Variance	16.6	32	248.8	248.8	248.8

Table 2: Testing the impact of communication costs on the concentration of HQ and MP.

Communication Costs	1.1 - 1.5	1.5 - 1.9
Head quarters	12.49	0.00
Manufacturing Plants	8.21	3.07

Table 3: Testing the impact of different managerial structures on the concentration of HQ and MP.

Communication Costs	1.1	1.5	1.9
Head quarters	0.00	3.78	3.78
Manufacturing Plants	5.06	3.08	1.67

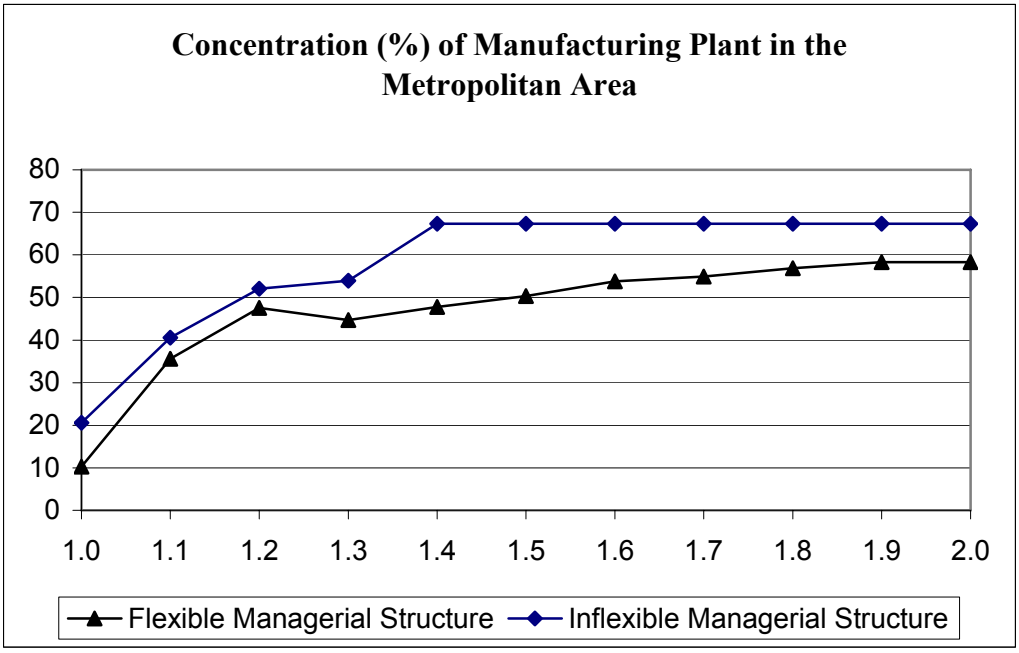

Figure 1: Concentration (%) of Manufacturing Plant in the Metropolitan Area

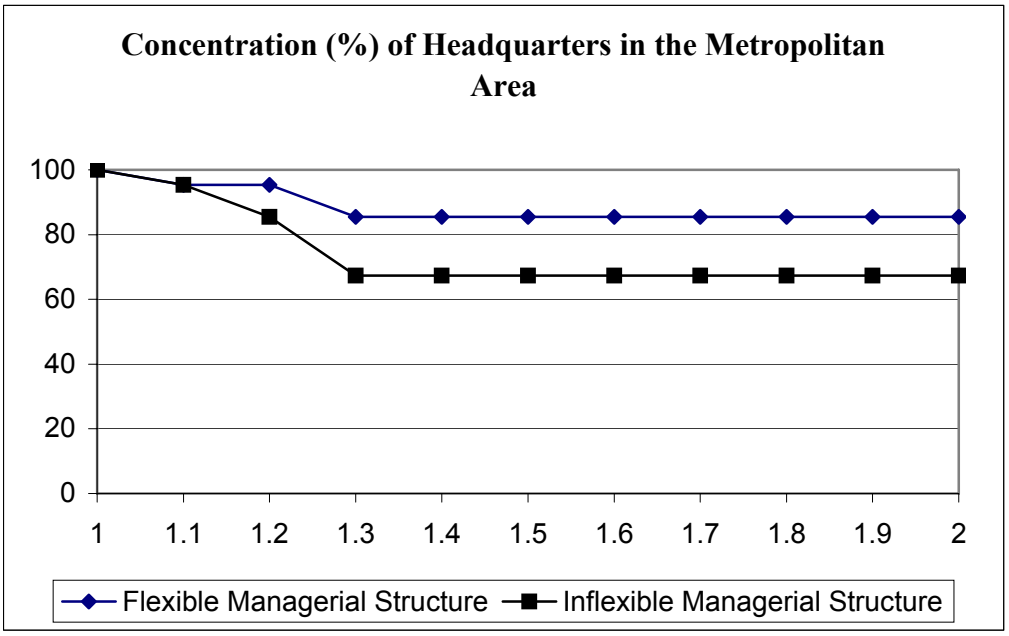

Figure 2: Concentration (%) of Headquarters in the Metropolitan Area