Essays on Firms' Location and Cooperation in Research & Development

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Biographic Note

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Abstract

This thesis aims at explaining how firms competing in the product market and benefiting from technological spillovers decide about its location and R&D cooperation.

First, we intend to evaluate if firms' decision about location revises when firms cooperate or compete in R&D. Through a strategic interaction model where firms decide about location, R&D and output, we concluded that if firms compete in R&D, the clustering of firms only occurs for a convex spillover function, while if R&D activities run cooperatively, clustering is always observed if there is an increased information sharing between firms.

A related topic concerns with the influence of spatial competition on firms' decision about location and R&D cooperation. We concluded that, for sufficiently high transport costs, cooperating firms prefer to disperse between regions than to agglomerate, while if transport costs are low, firms will agglomerate if uncertainty is high.

In the final chapter, we intend to evaluate the determinants of firms' location choice, according to its technological intensity and structure. We focus on the location choices made by Portuguese new manufacturing plants. The set of explanatory variables includes production costs, demand indicators, agglomeration economies and R&D expenditures. The model is based on the random utility maximization framework and proceeds through a Poisson model and a Negative Binomial regression. We then concluded that for the total manufacturing sector, the main determinants for firms' location decision are the agglomeration economies and both labor and land costs. However, when we consider firms' structure, we observed that new multi-plant firms are particularly sensitive to urbanization economies, land costs and local market, while new single-plant firms are more responsive to labor costs and agglomeration economies. Additionally, when considering the high-tech sample, we notice that the costs variables lose importance, while the urbanization economies and the R&D expenditures gain a particular relevance.

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Chapter 1

Introduction

Since long time ago, economic agents – households and firms – concentrate in few places - cities or industrial clusters[1]. During the last decades, this apparently widely accepted evidence has gained a very special attention in the core of urban and regional science but also attracted economists from other fields of economic science, like international economics, industrial organization or growth theory.

The evidence and secular tendency for the agglomeration of economic activities lead us to formulate some questions: *why do households concentrate in large metropolitan areas even though empirical evidence suggests that the cost of living is typically higher than in smaller urban areas* (Richardson [168])? Or, *why competing firms agglomerate in industrial clusters if competition there is fiercer* (Becattini [23])? Broadly speaking, *what*

[1]In fact, the percentage of world urban population increased from 29.1% (1950) to 47.1% (2000) of total population (UN [187]). Furthermore, examples of specialized and highly productive industrial clusters, such as the Silicon Valley and Route 128 (USA), the industrial districts in Italy (Prato, Sassuolo, Toscana, Emilia Romana and others), France (Troyes, Besançon, Choletais), Spain (Valles) or Portugal (Vale do Ave, Marinha Grande, Entre Douro e Vouga), among others, spurred literature (Mota [144]).

determines the location decision of economic agents and, therefore, the spatial organization of economic activity?

These questions are at the heart of *location theory*, and therefore, in the core of regional science. According to Greenhut and Norman [76], location theory aims at explain the use of a finite resource - *space* - by explicitly recognizing that economic activities consume space and are separated by costly distance. Location theory has a long historical tradition, as it goes back, for instance, to Smith and Ricardo, but its interest has been historically cyclical. In fact, alongside with some remarkable developments, such as Von Thünen [193], Launhardt [126], Marshall [136], Weber [195] and Lösch [131], location theory has seen some less enthusiastic periods. Fortunately, in the last decades, economists have been increasingly recognizing the relevance of *space* and *location theory*. Particularly, it has been realized that location theory is remarkably powerful as a method and can be applied to a wide range of microeconomics problems that arise, for instance, in new industrial economics or in social choice - see, for instance, the *theory of product differentiation*, rooted in Hotelling [98].

A typically divorced topic deals with the cooperation in Research and Development (R&D) activities by competing firms. Assigned to industrial economic literature, R&D cooperation models usually assume that firms may engage in R&D cooperation, even if being strong competitors in the product market, in order to internalize R&D spillovers. Since the earlier contributes of d'Aspremont and Jacquemin [48] and Kamien, Muller and Zang [118], several extensions were made, focusing, in particular, on the R&D spillovers and considering them as endogenous, asymmetric or uncertain. But, although it seems to be reasonable that firms' decision about R&D cooperation relates with its geographical location, very few articles make the R&D spillover and the R&D cooperation decision depend on firms' geographical distance and accordingly, on location choice[2].

Understanding the motivations that lead firms to select its location is the main purpose of this research. More precisely, we expect that this research would help us to explain how firms competing in the product market and benefiting from technological spillovers de-

[2]See, at this purpose, Long and Soubeyran [130], Baranes and Tropeano [19] and Piga and Poyago-Theotoky [161].

cide about its geographical location and about cooperation in R&D. Inspiration was found on literature about industrial clusters, which evidences that competing firms geographically co-located frequently adopt mechanisms of cooperation between them[3]. Additionally, literature on the geography of innovation also evidences the relevance of knowledge spillovers for the clustering of firms and for the emergence of cooperative behaviors[4].

The research background includes location choice models that put emphasis on knowledge spillovers and strategic interaction between firms. Additionally, we will have under consideration R&D cooperation models that assume endogenous knowledge spillovers that depend on firms' location.

The thesis will have three main chapters that correspond to autonomous essays under the main research topic of firms' location choice. The research questions explored in each chapter are the following ones:

1st) *Does firms' decision about location revises if they cooperate or compete in R&D and benefit from diverse knowledge spillovers?*

More precisely, we intend to evaluate if competing firms that benefit from endogenous knowledge spillovers that are distance-sensitive revise their location choices if they compete or cooperate in R&D. Inspiration was found on empirical literature about Marshallian industrial districts that evidences a strongly competitive environment between firms, which benefit from external economies but simultaneously develop cooperative agreements.

Having under consideration both location choice models and R&D literature, we developed a strategic interaction model where firms decide about location, R&D and after-

[3]According to Brusco [31], the interactions between firms in an industrial cluster include cooperative and strategic alliances that results from the characteristics of "social networks" of the cluster. Also, Camagni [33] suggests that cooperation between firms in an industrial cluster might be characterized by explicit cooperation networks or informal collaboration between firms. He also suggests that cooperation facilitates collective learning processes and reduce uncertainty, which favours innovation.

[4]The clustering of innovative-related firms is largely demonstrated in literature [e.g. Jaffe, Trajtenberg and Henderson [116], Carrincazeaux, Lung and Ralle [35] and Verspargen and Schoenmakers [191], among others), while some authors demonstrated the relevance of knowledge spillovers for cooperation between firms or between firms and other R&D interfaces (e.g. Cassiman and Veugelers [36], Belderbos, Carree and Diederenetal [24] and Fritsch and Franke [63]).

wards engage in Cournot competition. Firms' decision about location determines a R&D spillover, which is inversely related to the physical distance between firms but could be increased through cooperation. Additionally, the R&D output is assumed to be cost-reducing and exhibit diminishing returns. Our results allow us to conclude that there is a positive relationship between R&D output equilibrium and the distance between firms if firms act independently, while the opposite happens if firms cooperate in R&D. Additionally, if firms compete in R&D, the clustering of firms only occurs for a convex spillover function, while if R&D activities run cooperatively, clustering is always observed if there is an increased information sharing between firms.

2nd) *Does spatial competition among firms influences its decision about location and cooperation in R&D?*

A related question concerns with firms' decision about location and cooperation in R&D under spatial competition. In this case, we adopt a broad approach to the location-R&D cooperation problem that could reproduce, for instance, the location choice of competing firms between countries and its impact on the R&D cooperation decision. For our purpose, we developed a three stage game between two firms to evaluate if its location choice in two symmetric regions affects its decision to cooperate or compete in R&D. Firms face positive transport costs between regions and may benefit from a knowledge spillover if they were agglomerated, while if they were dispersed, no spillover will occur. In the R&D stage, firms must decide about its cost-reducing R&D output, independently or under cooperation. Moreover, if firms cooperate in R&D, they must decide about the amount of know-how to disclose to the research joint project. We then assumed that proximity between firms augments the confidence between entrepreneurs and reduces uncertainty in the disclosure of know-how.

From our results, we were able to conclude that, if transport costs are sufficiently high, firms will disperse between regions and cooperate in R&D in order to overcome the absence of R&D spillovers. In contrast, if transport costs are low, cooperating firms will agglomerate if the probability of disclosing information is low, while they will disperse if this probability is high in order to lessen the weight of transport costs.

3rd) *What determines firms' location choice?*

Specifically, we intend to evaluate the importance of both geographical, sectorial and technological determinants for firms' location choice, according to its technological intensity and structure. For that purpose, we make use of micro-level data for the Portuguese manufacturing sector and focus on the location choices made by new starting plants. We considered the entire manufacturing sector, and also samples according to the number of plants and firms' technological intensity. The set of explanatory variables includes variables that are traditionally stressed by urban and regional theory, such as production costs, demand indicators and agglomeration economies, as well as technological variables, such as R&D expenditures. The model is based on the random utility maximization framework and proceeds through a Poisson model and a Negative Binomial regression.

From our results, we were able to conclude that for the total manufacturing sector, the main determinants for firms' location decision are the agglomeration economies and both labor and land costs. However, when we consider the multi-plant versus the single-plant location choices, we observed that new multi-plant firms are particularly sensitive to urbanization economies, land costs and local market, while new single-plant firms are more responsive to labor costs and agglomeration economies. Additionally, when considering the high-tech sample, we notice that the costs variables lose importance, while the urbanization economies and the R&D expenditures gain relevance.

The thesis is organized as follows. Next chapter is devoted to a brief dissertation about the importance of space and location theory in economic science. Afterwards, we proceed through economic modeling to study the influence of firms' decisions about location on R&D cooperation under knowledge spillovers. Subsequently, we evaluate if spatial competition among firms influences its decision about location and cooperation in R&D. Finally, we proceed through empirical modeling to evaluate the importance of geographical, sectorial and technological determinants for firms' location choice. We finish with some final remarks.

Chapter 2

Location and Spatial Economics

One of the most salient features of the world economic development is the agglomeration of economic activity in a small number of cities or industrial clusters. As researchers, we are therefore led to ask: *how does economic theory explains the agglomeration of economic activity*? Answering this question applies for the development of economic models that specifically integrates space in economic analysis. But what is *spatial economics*? Briefly speaking, and according to Duranton [54], spatial economics is concerned with the allocation of resources over space. Clearly, its main focus is location choice, but it could deal with almost anything economics is concerned about.

We then turn to a central question: *how does economic models deals with space and explain the location choices of economic agents?* Our starting point is the neoclassical paradigm, which assumes perfect competition and constant returns to scale. So, is spatial economics only about adding a spatial dimension to the neoclassical models? According to Fujita and Thisse [67], the neoclassical economic theory is developed on the basis of a set of simplifying assumptions that avoid the assimilation of space in the analysis. If we have under consideration the orthodox model of Arrow and Debreu [13], then each commodity would be defined by all its characteristics, including its location: the same good traded in different locations must be treated as a different good. This seems to obviate the need for a theory that specifically integrates space. So, under the constant returns to scale and perfect competition paradigm, economic activities will be evenly distributed across the homogenous space.

But, as Starrett [179] enunciated in his *Spatial Impossibility Theorem*, *if space is homogenous and transportation of goods is costly, then any possible competitive equilibrium (if it exists) is such that no transportation of any good can occur in the entire economy.* This means that if economic activities are perfectly divisible and transport is costly, then there exists a competitive equilibrium such that each location operates as an autarchy to save on transport costs and no agglomeration is observed. We then have that the perfect competitive price mechanism, alone, cannot endogenously generate economic agglomerations. Instead, if we assume imperfect divisibility of economic activities, which justifies positive transportation costs between locations and the non-convexity of the set of feasible locations, then there is no competitive equilibrium.

In consequence, and according to Fujita and Thisse [67], to understand the spatial distribution of economic activities, and in particular, the formation of economic agglomerations, we must adopt at least one of the following assumptions: *space is heterogeneous*, as in comparative advantage models or in pioneering static location models; *markets are imperfect*, as in spatial competition theory or in monopolistic competition models with increasing returns; there are *externalities in production and/or in consumption*, as in externality models.

2.1 Comparative advantage models

One possible way to deal with space in economics is founded on the international trade framework. This approach assumes that *space is heterogeneous* by considering the uneven distribution of immobile resources and amenities across space, as well as the existence of transport nodes. It builds on David Ricardo's theory of economic rent that relies on differentials on land relative productivity, which was later extended to the consideration of Hecksher-Ohlin's theory of trade that assumes differences in relative factor endowments over space. The Ricardian-Hecksher-Ohlin approach then explains the location of economic activities based on the existence of (exogenous) *comparative advantage* among locations, which gives rise to interregional and intercity trade. Additionally, it retains the assumption of constant returns and perfect competition, and so, it can be easily incorporated in Arrow-Debreu's framework. However, and according to Duranton [54], this approach plays a minor role in the development of spatial economic theory, as it provides a partial explanation for the location patterns within a country.

2.2 Static location models

Instead, pioneers in spatial economics have focused on location choice by assuming that there are non-convexities in the set of feasible allocations that result from *positive transport costs*. This was the case of Von Thünen [193], who developed the first formalization of spatial economics. Von Thünen intended to study the patterns of land use when land is homogeneous and transportation costs to a monocentric city are costly. Under these assumptions, spatial equilibrium typically involves concentric rings around the city, being the use of land determined by both the output revenue and the inputs costs, land rent and transportation costs. According to Fujita and Thisse [66], Von Thünen's model is still compatible with the competitive paradigm, as it assumes constant returns to scale and perfect competition and, as a result, the market outcome is likely to be socially optimal.

Despite the now well recognized importance of its contributes, Von Thünen's ideas idled for more than a century without attracting significant attention. Subsequent research on land use includes Alonso [3], who extended the von Thünen's central concept of bid-rent curves to urban context in which the monocentric city is replaced by a central business district.

It was almost at the end of the nineteenth century that space emerged again on the economic analysis, with the works of Launhardt and Weber. Focusing on the industrial location choice, Launhardt [126] explained the optimal location choice of an industrial plant as the site where the transport costs of both inputs and output were minimum. However, the most prominent author on industrial location theory is Weber [195], who studied the location choice of a competitive and indivisible firm that faces transport costs for both inputs and output. In Weber's framework, all buyers are concentrated at a given buying center and each seller locates with respect to the buying center. Price is given and there is no location interdependence between firms. Then, the optimum location of the firm depends on the ratio between quantities of inputs and outputs and also on the relative transport rates on each of the goods shipped.

In spite of abstracting from input substitutability, market demand or the location interdependence between firms, Weber's influence was universal. With the exception of Palander [156] and Hoover [97], who were concerned with the size of the firm's market area and therefore, with demand variables, most subsequent works abstract from market variables. For instance, Predöhl [165] and Isard [112] developed a cost analysis, Moses [143] allowed for input substitution and concluded for a simultaneous co-determination of both optimum input combination and optimum location of the firm and Linke [129] stressed labor and agglomerative differentials in explaining and measuring industrial displacements from transport centers.

2.3 Spatial competition models

Another line of research in spatial economics develops on the contributes of Hotelling [98], Fetter [57], Lerner and Singer [128] and Chamberlin [37] and focus on the spatial interaction between firms by assuming *oligopolistic competition* between them. In this case, firms are no longer price-takers and make price policy dependent on the spatial distribution of consumers and firms. This generates some form of direct interdependence between firms and households that may produce agglomeration, while the market outcome is inefficient. It departs from oligopolistic competition models, which assumes a finite number of large agents who interact strategically by accounting for their market power.

In Hotelling [98]'s model, firms simultaneously choose its location and afterwards set their prices. He assumed that buyers were scattered over an area and production costs were equal at all locations, while delivered price varies with location. Each firm is able to sell to the nearest buyer at delivered prices if they are lower than its rivals' ones, which lead the seller to become a local monopolist. As a result, spatial competition between firms lead firms to concentrate, a result known in the literature as the *principle of minimum differentiation*.

In a subsequent work, Chamberlin [37] demonstrated that Hotelling's principle of agglomeration was not robust, being necessary to introduce agglomeration economies. Lerner and Singer [128] demonstrated that the optimal location of the firm is influenced by the elasticity of the industrial demand curve, the height of the freight cost and the characteristics of the marginal production costs. They also concluded that agglomeration only occurs if demand is inelastic and in the absence of fixed transportation costs. Treading on Hotelling's footsteps, Kaldor [117] assumes that consumers will buy from the firm with the lowest "full price", including transport cost, and therefore, each firm competes only with its neighbors, independently of the total number of firms in the industry.

In a world wide cited paper, d'Aspremont, Gabzewics and Thisse [47] have shown that no price equilibrium exists if firms were located close enough to each other. They concluded that spatial competition between firms does not imply agglomeration because firms whish to differentiate in order to reduce the intensity of price competition. Therefore, the principle of minimum differentiation could only hold if an additional differentiation dimension is allowed. For instance, by assuming product differentiation (Ben-Akiva, De Palma and Thisse [27]) or consumers heterogeneity (De Palma *et al* [49] and Anderson, De Palma and Thisse [7]) or by considering spatial Cournot competition (Hamilton, Thisse and Weskamp [84] and Anderson and Neven [8]).

2.4 Monopolistic competition and increasing returns

According to Fujita and Thisse [66], the assumption of *increasing returns* is essential for the explanation of the emergence and growth of economic agglomerations. In fact, scale economies are a strong centripetal force, either because it makes profitable for firms to concentrate in a few number of plants, or because it makes larger markets more attractive for firms, thus triggering a cumulative process of agglomeration. Actually, under non-increasing returns and a uniform distribution of resources, the economy would reduce to a Robinson Crusoe type, where each individual would produce only for his own consumption[5]. This was recognized by early location theorists, such as Christaller and Lösch, and undertaken by new economic geographers, like Krugman and Venables.

2.4.1 Early contributes

Christaller and Lösch assumed that scale economies in production, as well as in transportation costs, were essential to understand the location of economic activities. Chistaller [41]'s *Central Places Theory* focus on the location choice of services that are market oriented. In his model, population and demand were homogeneously distributed in an isotropic space while supply was concentrated in cities. As a result, it emerges a hierarchical system of places around a city (the centre of the community) that results from the correspondence between the spatial distribution of supply and demand, the strength of this correspondence varying from function to function and being dependent on the economies of scale and transportation costs. The Christaller hexagonal system then provides a plausible spatial structure, involving a hierarchical system of centres, but somewhat restrictive, as it was difficult to apply. Extensions and modifications to Christaller's *Central Places Theory* have been proposed, the foremost contribution is due to August Lösch.

[5]According to Fujita and Thisse [66], an unequal distribution of resources seems to be insufficient to serve as the only explanation for location choice. Accordingly, we can therefore conclude that increasing returns to scale are essential for explaining the geographical distribution of economic activities ("folk theorem of geographical economics").

Lösch [131] developed a model of monopolistic competition that assumes indivisibilities in production and positive transport costs. He conceived a homogeneous and isotropic landscape where population has identical preferences and is evenly and continuously distributed. Additionally, he assumed that firms face identical technological conditions and entry is free. As consumers pay for transport costs, which are linear with the distance, he was able to derive the demand over space for a single-good and, therefore, each seller's market area. He then concluded that positive profits will induce rivals to enter in the market, which results into a hexagonal zero-profit market-area for each seller. Lösch recognized that different industries would possess different-size hexagons which in turn would generate different inter-industry concentrations. The extent of the concentration of production depends both on increasing returns to scale and on the transportation costs[6]. He then generalized his model to the *n*-good case, which revealed to have too many inconsistencies to yield a stable system-wide equilibrium.

Subsequent research includes Isard [112], who reformulates spatial economic theory by integrating the contributes of Von Thünen, Weber, Christaller and Lösch, and also Greenhut [74] [72], who focus on the profit maximization location choice and on the spatial distribution of firms and its relation with pricing policies.

2.4.2 The new economic geography

In recent years, a new approach emerged within economic geography that puts emphasis on pecuniary externalities and merges them into a general equilibrium model of monopolistic competition. On one side, imperfect competition is more suitable to encompass pecuniary externalities, as prices do not perfectly reflect the social values of individual decisions. On the other side, general equilibrium analysis allows to account for the interaction between the product and labor markets. Additionally, and as the explanation for the agglomeration of the economic activity is based on some distortions of the market mechanism, market outcomes are likely to be inefficient. This new approach finds its roots

[6] In fact, we have that the greater the extension of the increasing returns to scale, the smaller the number of production points. Similarly, the higher level of transportation costs, the greater the number of production points (Parr [157]).

on the seminal paper of Krugman [124] and it has become known as the "new economic geography".

Krugman [124] suggested that industry agglomeration is the result of demand linkages between local firms developed by the interaction of transport costs and economies of scale. The starting point for his approach is the monopolistic competition model à la Dixit and Stiglitz [53], which assume that each firm is negligible in the sense that it may ignore its impact on other firms, but retains enough market power (given by increasing returns) for pricing above marginal cost, regardless of the total number of firms. Also, each firm's demand depends on the actions taken by all firms in the market, but, although firms are price-makers, strategic interactions between them are very weak[7].

Combining the Dixit-Stiglitz model with an iceberg-type transport cost, Krugman examine the conditions under which a country can endogenously become differentiated into an industrialized "core" and an agricultural "periphery". The model is simply described as a two-sector economy, where agriculture and industry produce, respectively, a homogeneous good under constant returns and a differentiated good under increasing returns. The development of the model and its resolution for the transport costs parameter allows for the prediction of a monotonic decreasing relationship between the degree of agglomeration and the level of transport costs. Krugman also suggested that the details of the geography that emerges - the regions "core" and the regions "periphery" – depends sensitively on the initial conditions, so that history matters[8].

In the last decade, this strand of the literature has grown exponentially (see Fujita, Krugman and Venables [64] for a comprehensive analysis). Several extensions to the original Krugman's model have been proposed, which introduced more realistic assumptions:

[7]Krugman's approach offers a formalization of Myrdal [145]'s theory of *circular and cumulative causation* and Hirschman [93]'s model of unbalanced growth with *backwards and forwards linkages*.

[8]In spite of the relevance of Krugman's findings, it becomes necessary to find out how they are related with its model's assumptions and whether its assumptions are realistic. In fact, the use of both CES utility and iceberg transportation costs, while extremely convenient, conflicts with research in spatial pricing theory and may be unrealistic. Additionally, the assumption of interregional labour mobility seems to conflict with some empirical cases, as, for instance, the European case. Other assumptions could also be relaxed, as the assumption of zero transport costs for the homogenous good or the homogeneity of workers' preferences. Additionally, the assumption of free entry and exit leads to zero profit so that a worker's income is just equal to his wage. Last, the difference between price competition and quantity competition is immaterial in a monopolistic competition setting.

Venables [190] assumed inter-sectorial rather than interregional labor mobility; Fujita, Krugman and Venables [64]) assumed positive transport costs for both traditional and modern sector; Ottaviano [153] considered the influence of workers' expectations on the process of agglomeration; Ottaviano, Tabuchi and Thisse [154] introduced quasi-linear utility functions and linear trade costs; Tabuchi and Thisse [184] assumed that workers' preferences were heterogeneous. Extensions to a dynamic setting were also developed, as it was the case of Martin and Ottaviano [137], who merged a model of endogenous growth with a new geography model and demonstrate that aggregate growth and spatial agglomeration were self-reinforcing processes.

Although the details of the agglomeration process vary with the models, there is, in general, support for the emergence of a core-periphery structure and for a trade-off between transport costs and agglomeration. These conclusions agree with the evidence of a secular fall in transportation costs and the intensification of the geographical concentration of economic activities.

2.5 Externalities

Another reason for agglomeration comes from *external economies*. According to Marshall [136], the clustering of firms may arise from (i) mass-production (or internal scale economies) and external economies, such as (ii) the formation of a highly specialized labor force based on accumulation of human capital and face-to-face communications, (iii) the availability of specialized input services and (iv) the existence of modern infrastructures.

The now standard classification of Marshallian external economies[9] is attributed to Hoover [96] and distinguishes between *urbanization economies*, which are external to firms and

[9]The concept of external economies has been subject to a great effort of precision. According to Scitovsky [174], there are two concepts of external economies: technological externalities (or spillovers) and pecuniary externalities. The former deals with the effects of non-market interactions, which are realized through processes directly affecting the utility of an individual or the production function of a firm. By contrast, the latter refers to the benefits of economic interactions, which take place through usual market mechanisms via mediation of prices. Marshallian externalities are a mixture of both technological and pecuniary externalities.

industries but internal to a city, and *localization economies*, which are external to firms but internal to an industry. More precisely, and according to Henderson [90], *urbanization economies* reflect the benefits from operating in large population centres with correspondingly large, overall labor markets and large, diversified service sectors to interact with manufacturing. On the other hand, *localization economies* could reflect economies of intra-industry specialization that permit a finer division of the production function among firms, labor market economies that reduce search costs for firm seeking workers with specific training and communication economies that can speed up the adoption of innovations.

The evidence shows that both types of external effects are at the origin of several specialized and prosperous areas. According to Porter [162], externalities are maximized in regions with geographically specialized and competitive industries, and so, localization economies are the main reason for the success of industrial clusters. In contrast, Jane Jacobs [114] believes that the most important knowledge transfers come from outside the core industry, which supports the relevance of urbanization economies.

Typically, externality models appeal to the constant returns and perfect competition paradigm while assuming that the main forces for agglomeration comes from non-market interactions between firms and/or households. Literature frequently focus on city formation, as it was presented by Henderson [89] and Black and Henderson [28], as well as on industry clustering modelling, such as Glaeser *el al* [70], Soubeyran and Thisse [177] and Belleflame, Picard and Thisse [26].

2.6 Some final remarks

According to Simões Lopes [176], although space has been neglected in the mainstream of economic theory, its importance is recognized for a long time. As we mentioned above, traditional general equilibrium models employ space as an additional characteristic of each commodity but revealed to be unable to explain the endogenous formation of economic agglomerations. As a consequence, and in order to account for space in economic questions, it is necessary to introduce additional assumptions, such as heterogeneity in space, imperfect markets or externalities.

What is spatial economics concerned with? If we adopt a broad perspective and think that economic activity has to take place somewhere, then spatial economics may relate with almost anything economics is concerned about. In fact, and according to Duranton [54], topics such city growth, technological spillovers or social networks still have a spatial dimension, whilst its importance remains to be determined. Undoubtedly, the main focus of spatial economics concern with the location choice of economic agents. Questions such as: *why do firms cluster in some regions*, or, *why do cities exist*, are at the core of spatial economics.

The overview of main contributes for spatial economics is the starting point for our research, which focus on the topic of firms' location under knowledge spillovers.

Chapter 3

Firms' Location and R&D Cooperation in an Oligopoly with Spillovers

3.1 Introduction

Ever since Marshall [136], it is widely accepted that firms gain from their joint location because they benefit from economies on the transport of goods, people and ideas. However, if firms are rivals in the product market, geographical proximity makes competition between them fiercer and this acts as a centrifugal force. Obviously, the outcome of both centripetal and centrifugal forces depends on their relative strengths. Additionally, even if being strong competitors in the product market, firms frequently adopt a cooperative behavior in what concerns, for instance, Research and Development (R&D) activities (e.g. d'Aspremont and Jacquemin [48] and Kamien, Muller and Zang [118]).

This chapter aims at explaining if firms's decision about location revises when firms cooperate or compete in R&D and benefit from diverse knowledge spillovers. For that purpose, we developed a three-stage game amongst three firms where each firm decides about location, R&D and output. We assumed that firms' decision about location determines a R&D spillover, which is inversely related to the distance between firms. Also, the R&D output is presumed to be cost-reducing and exhibit diminishing returns. As expected, cooperation is only allowed in the R&D stage.

Our results allow us to conclude that there is a positive relationship between R&D output equilibrium and the distance between firms when firms act independently. When firms cooperate in R&D, the R&D output for a cooperating firm increases with the degree of information sharing between them, as well as with a reduction of the distance between cooperating firms. Firms' decision about location is also affected by R&D activities: if R&D activities run independently, the clustering of firms only occurs for a convex spillover function; if R&D activities run cooperatively, clustering is always observed if there is an increased information sharing between firms.

In the next section, we discusses the theoretical framework on R&D cooperation games and location choice. Subsequently, we proceed with a sketch of the model, which is presented in two scenarios - competition and cooperation in R&D - and enunciate the propositions concerning our research goal. Finally, we will end with some concluding remarks.

3.2 Research Background and Motivation

It has been long recognized that knowledge spillovers are a major influence on firms' location choice, alongside with the access to a pooled market for skilled labor, the availability of specialized inputs and the existence of modern infrastructures (Fujita and Thisse [65]). The idea is rather simple: spillovers occur more easily if geographical proximity is observed, as ideas flow more easier over shorter distances. In effect, literature on the geography of innovation usually confirms the existence of geographically mediated spillovers that are distance-sensitive (e.g. Jaffe [115], Jaffe, Trajtenberg and Henderson [116], Anselin, Varga and Acs [9], Carrincazeaux, Lung and Ralle [35], Adams [1], Arundel and Geuna [14], Verspargen and Schoenmakers [191] and Audretsch, Lehmann and Warning [18], among others). At the same time, knowledge spillovers seem to be at a great extent responsible for the emergence of cooperative behaviours between firms or between firms and other R&D interfaces (e.g. Cassiman and Veugelers [36], Belderbos *et al* [24], Fritsch and Franke [63] and Veugelers and Cassiman [192]).

The purpose of this research is to evaluate wether firms' decision about location revises if firms cooperate or compete in R&D and benefit from knowledge spillovers. For that end, we will develop a strategic interaction model that merges the topic of firms' location within a R&D decision game. Two strands of the literature converges to our goal: on one side, the industrial economics approach to the topic of R&D cooperation; on the other side, the regional economics research on the issue of firms' location.

3.2.1 R&D cooperation games

It is generally recognized that R&D activities have some public good features, as firms cannot fully appropriate the returns of their R&D investments, due to the existence of R&D spillovers. As a result, R&D expenditures are usually less than socially optimal. For this reason, R&D cooperation frequently emerges, so as to internalize spillovers. Other advantages of R&D cooperation are to capture the economies of scale or complementarities in R&D, as well as potential beneficial effects coming from firms' coordination of research activities and the diffusion of know-how and R&D output among cooperating firms. Against these advantages is the fear that the participating firms may free-ride on other firms, as well as the possibility of reduction of competition in the product market, which would result in a welfare loss.

Cooperation in R&D is usually identified with research collaboration and is often investigated in the context of two-stage oligopoly models in which firms make their R&D decisions in a first pre-competitive stage and their quantity/price setting in a second stage.

The first attempt to analyze R&D cooperation in oligopolist markets was made by Katz [121], who proposed a four-stage model of process innovation to examine the formation of a Research Joint Venture (RJV). He assumed that firms behave noncooperatively, but can agree to form an independent R&D lab. Katz concluded that industry-wide agreements tend to have socially beneficial effects when the degree of product competition is low, when there are R&D spillovers and when the agreement concerns basic rather than development research.

The most influential article on R&D cooperation is due to d'Aspremont and Jacquemin [48], who assumed that there are spillovers in R&D output and concluded that, for a large spillover coefficient, the collusive level of R&D was higher than the non-cooperative one. Another prominent work is Kamien, Muller and Zang [118], which proposed spillovers in R&D expenditures and allowed for different R&D organization models that may involve R&D expenditures cartelization and/or full information sharing. They have shown that Research Joint Venture (RJV) competition was the least desirable model as it yields higher product prices, while RJV cartelization was the most desirable, because it provides the highest consumer plus producer surplus under Cournot competition, and, in most cases, under Bertrand competition[10].

Since these starting articles, a lot of scientific models emerged around the topic of R&D cooperation, providing numerous extensions to those original models. Particularly relevant for our research are the extensions to a oligopolistic scenario with industry-wide agreements. This was the case of Suzumura [182], who concluded that for large spillovers, neither noncooperative nor cooperative equilibria achieve even second-best R&D levels, while in the absence of spillovers effects, the noncooperative equilibrium seems to overshoot the social optimal level while the cooperative R&D does not reach a social optimum. Also in the context of an oligopolist industry but allowing for cooperation among a subset of firms is Poyago-Theotoky [163]. She demonstrated that there was an inverse relationship between the development of R&D activities and the degree of an exogenous

[10] Although Kamien, Muller and Zang's model seems a priori more appropriate for an universal use, most literature adopted D'Aspremont and Jacquemin's methodology (see Amir [4] for an analytical comparison of both models).

R&D spillover: as the spillover coefficient increases, firms see a larger proportion of the results of their R&D activity flow over to the other firms, which lead them to reduce its R&D activities.

Additionally, we found some quite interesting articles that make the R&D spillover endogenous. It was the case of Katsoulacos and Ulph [120], who intended to examine the effects of a RJV when R&D spillovers are endogenous. They considered that the spillovers among firms depend both on the adaptability of the research and on the amount of information sharing among them. They demonstrated that noncooperation can produce maximal spillovers and that a RJV may behave in an anti-competitive way by choosing partial RJV spillovers or by closing a R&D lab. Also, Poyago-Theotoky [164] considered a typical R&D-output duopoly game but assumed that the R&D spillover results from a strategic decision made by firms. After having evaluated the scenarios of R&D competition and R&D cooperation, she concluded that R&D cooperation leads firms to engage in more R&D but also make them completely disclose its know-how. As well, in Amir, Evstigneev and Wooders [5]'s article, cooperating firms choose the optimal level of the spillover parameter. It is shown that the optimal cartel always prefers extrema spillovers.

Other authors considered some specificities or asymmetries in R&D spillovers. Vonortas [194] considered diverse degrees of spillover between cooperating firms, according to the type of research: generic research would produce higher spillovers than specific research. He then concluded that joint ventures that simply allow members to coordinate their actions can improve firms' incentives for R&D over non-cooperation only in the presence of high knowledge spillovers, while if joint ventures additionally improve information sharing among firms will raise social benefits, even in the presence of relatively insignificant spillovers. Steurs [180] tried to evaluate the importance of both inter and intra-industry R&D spillovers. He concluded that inter-industry R&D spillovers have a very important effect on firms' incentives to invest in R&D both directly and indirectly, because of their influence on intra-industry R&D spillovers. Also, R&D agreements that cut across industries may be more socially beneficial than cooperatives whose membership comes from a single industry. Amir and Wooders [6] assumed one-way spillovers from the firm with higher R&D activity to its rival (but never vice-versa) through a binomial function. They demonstrated that no equilibrium can be symmetric even though the two competing firms were *ex-ante* identical. Thus, an industry configuration emerges with a R&D innovator and a R&D imitator. Additionally, they compared the performance of a RJV with a join lab or pure R&D competition and concluded for the superiority of the joint lab over R&D competition.

Other approaches introduce the concept of *absorptive capacity*, which means that each firm needs to conduct its own R&D in order to realize spillovers from other firms' R&D activity [Cohen and Levinthal [43], Kamien and Zang [119] and Grünfeld [77]]. Alternatively, some papers involve dynamic models, as it was the case of Petit and Tolwinski [160], who extended the existing literature on cooperative/competitive R&D into a context of a dynamic model. Finally, and in the context of uncertainty and contracts theory, several articles have been produced, from which we may distinguish Macho-Stadler and Pérez-Castrillo [132], Choi [39], Morasch [142], Pérez-Castrillo and Sandonís [159] and Cabral [32], among others.

3.2.2 Location choice under knowledge spillovers

According to Isard and Smith [113], one of the basic problems which has long plagued location theorists has been the question of interdependent location decisions. In recent times, it emerged a large body of literature that recurs to game theory in order to study the topic of location choice. Historically, one set of these location games has centered around the Weberian agglomeration problem, while another has centered around the Hotelling spatial-competition problem.

As we have alraedy seen, Weber [195]'s theory of industrial location assumed a pure competition framework, as all buyers were located in a given buying center and the demand for each product was unlimited at the prevailing price. Also, the quantities of inputs used for production as well as the places where they were purchased were given a priory. Under this scenario, the optimal location of the firm corresponds to the site where the transportation costs of both inputs and output were minimum (Greenhut [75]). Extensions to Weber's model include Hoover [97], Palander [156], Predöhl [165] and Isard [112], among others.

On the other hand, spatial competition models typically assume that firms interact strategically with respect to location, as they encompass oligopolistic rivalry (Fujita and Thisse [65]). This approach finds its roots in the seminal work of Hotelling [98], according to whom competition for market areas is a centripetal force that would lead firms to congregate, a result known in the literature as the *Principle of Minimum Differentiation*. In a subsequent paper, d'Aspremont, Gabzewics and Thisse [47] demonstrated that the *Principle of Minimum Differentiation* was invalid, and since then, a considerable effort has been devoted to restoring the validity of that principle. For instance, by introducing enough heterogeneity in consumers (e.g. De Palma *et al* [49]) or by considering explicitly price collusion (e.g. Friedman and Thisse [62]).

Recently, location models have been extended to capture the topic of firms' location under knowledge spillovers[11]. Some authors focus on the relevance of Marshallian technological externalities for the location decision made by firms. This was the case of Belleflame, Picard and Thisse [26], who assume that the formation of regional clusters depends on the relative strength of three forces: the magnitude of localization economies, the intensity of price competition and the level of transport costs. They considered an oligopoly where firms producing a differentiated product decide to locate in two possible regions and then compete in prices. Also, they assumed that the marginal costs of production are a decreasing function of the number of similar firms located together. Then, they concluded that the impact of localization economies on location choice rises as transport costs between regions fall and as the market size increases. Soubeyran and Weber [178] considered an oligopoly where firms are heterogenous, due to distinct "stand-alone" district-dependend production and transportation costs. Every firm chooses its location among a set of industrial districts and its production costs is affected by local socio-economic spillovers that depend on the number of firms existing in that district. Thus, firms had under consider-

[11] In recent years, an alternative approach that puts emphasis on pecuniary externalities and merges them into a general equilibrium model of monopolistic competition emerges. This new approach finds its roots on the seminal paper of Krugman [124] and becomes known as the *core-periphery models*. However, it clearly overhead the purposes of this research that focus on technological externalities.

ation the reciprocal nature of cost-reduction as by joining a district, they engage in tacit cooperation: firms reduce its own costs but also the costs of their rivals. They demonstrate that a dispersed equilibria might emerge if firms and districts' characteristics possess sufficiently heterogeneity.

In a very interesting paper, Soubeyran and Thisse [177] focus on the collective learning-by-doing process and its impact on the development of industrial districts. They assumed that the cost function of a firm is a decreasing function of the total output produced in the past by the firms established in that local. Know-how is assumed to be individual workers-specific, which are immobile. They studied the dynamic of the regional system and concluded that the economy converges toward a balanced/unbalanced spatial structure, depending on the way workers interact to build their stock of knowledge.

In a rather different framework, Lai [125] proposed to evaluate the impact of technological spillovers on the location choices of duopolistic firms in a Weber triangle. He assumed that the technological spillover was decreasing with the distance between firms and it is cost reducting. He then concluded that, when the distance to the market is constant, then each firm's optimal location is independent of a demand shock. However, when the distance to the market is variable, a firm's optimal location will not be independent of a demand shock if one of the duopolistic firms has a non-linear technology. However, these authors do not model R&D spillovers explicitly.

Other approaches explicitly considered R&D spillovers but focus on its influence on the localization of R&D activities. Franck and Owen [60] focus on the role of country-specific stocks of knowledge on the R&D localization decision made by firms. Each firm's technological efficiency depends not only on its investment in applied R&D, but also on its absorption of domestic and foreign fundamental R&D, as well as the extent to which the later are substitutes or complements. Also, firm's absorption of foreign fundamental R&D depends on the decision to locate R&D activities abroad. They concluded that, in the case foreign and domestic knowledge stocks are substitutes, firms have fewer incentives to locate R&D in the foreign market, while the opposite happens when knowledge stocks are complementary.

Making difference between internal and external spillovers, Gersbach and Schmutzler [69] model a duopoly where firms choose production and innovation locations before Bertrand competition takes place. They allow for both internal communications and geographically bounded external spillovers. In their model, they find that higher external spillovers do not necessarily make agglomeration more likely, while efficiency of internal transfers promotes agglomeration of innovation. Sanna-Randaccio and Veugelers [171] focus on the trade-offs that a multinational (MNE) faces when organizing its R&D decentralized versus centralized. They allowed for both internal and external knowledge flows but ignore interaction effects with potential rival MNE's. They demonstrate that the relative market size loses relevance as a locational factor for R&D decentralization if the cost of intra-firm communications falls. Also, Belderbos, Lygogianni and Veugelers [25] model the R&D location choice made by two multinational firms competing both abroad and in their home markets. They considered both local inter-firm knowledge flows and international intra-firm R&D spillovers. In equilibrium, the shares of R&D performed abroad depend on the importance of spillovers, the strength of product market competition, the efficiency of intra-firm transfers and wether the firm is a technology leader or technology laggard.

Additionally, some articles focus on the role of R&D spillovers on production-location choice. Mai and Peng [133] presented a very simple model of spatial competition à la Hotelling that introduces an element of tacit cooperation through information exchanges between firms that are distance-sensitive. They have shown that equilibrium location can be achieved in a wide range from minimum to maximum differentiation depending upon the relative strength of the cooperation effect over competitive effect. Additionally, they concluded that the larger is the externality between firms, the less will be the location differentiation between them. Agata and Santangelo [2] developed a three-stage noncooperative R&D game with endogenous spillovers, where firms decide about its technological profile and geographical localization, R&D level and Cournot quantities. They assumed that the R&D spillovers are inversely related with the geographical distance between firms but also depend on the cognitive distance between firms. They then concluded that successful spillovers require co-localization and exclude technological sameness and technological dissimilarity. Also, Piga and Poyago-Theotoky [161] developed a three-stage duopoly model à la Hotelling where firms choose location, quality-enhancing R&D and price under the assumption that R&D spillovers depend on firms' geographical distance. They demonstrated that the higher is the degree of product differentiation (or alternatively, the higher the transportation costs), the higher is the distance between firms and the R&D effort.

To our knowledge, very few articles merges R&D cooperation decision with some models of location choice under R&D spillovers. It was the case of Long and Soubeyran [130], who conditioned the R&D spillovers to firms' decision about location and investigated how firms' decision about location is affected by the shape of the spillover function and by the decision of firms to cooperate or not in R&D. They concluded that the only Nash equilibrium for a duopoly with symmetric locations is the agglomeration one, while for an oligopoly with asymmetric locations, agglomeration is only guaranteed if the spillover effect is convex in distance. They also allow for R&D cooperation between a subset of firms and investigate under which conditions agglomeration and dispersion equilibria might emerge. In the context of asymmetric information games, Baranes and Tropeano [19] intended to explain why spatial proximity makes knowledge sharing between firms easier in the context of clusters of competing firms. They developed a model where firms must decide about location, researchers' wages, research's team formation and prices. Information asymmetry arises, as firms are unable to observe the researcher's effort or to verify the innovation size. Several equilibria emerge, depending upon both the transport costs and the research spillovers.

3.2.3 Motivation

The purpose of this essay is to explain if firms decision about locations revises under R&D cooperation or competition in the context of competing firms and knowledge spillovers. For that purpose, we developed a three-stage game amongst three firms where each firm decides about location and R&D expenditures and after that engage in Cournot competition. Similar to Long and Soubeyran [130] and others, we also considered that firms' decision about location determines a R&D spillover coefficient, which is inversely related to the physical distance between firms. As in d'Aspremont and Jacquemin [48], R&D output is assumed to be cost reducing and exhibit diminishing returns. Finally, inspired in Poyago and Theotoky [163], we also consider that only a subset of firms may cooperate in R&D through an increase of the spillover coefficient.

The model we developed is related to Long and Soubeyran [130], who considered a model of location choice by Cournot oligopolists with exogenous R&D expenditures. We extended it by introducing an intermediate stage where firms decide about R&D output. This allows us to evaluate the sensitivity of R&D output to the distance between firms, as well as to consider endogenous R&D outputs either if firms run R&D independently or in cooperation. Additionally, Long and Soubeyran evaluated how firms' decisions about location are affected by their decisions on R&D cooperation. However, as R&D expenditures' decisions are not taken under consideration, they assumed that firms cooperate in their location decisions if they collusively decide about R&D expenditures. Unlikely, we study the problem of an entrant firm choosing its location among two incumbent firms in a scenario of independent or R&D cooperation, whilst cooperation is only allowed in the R&D game. This corresponds to an updating to previous research, as there is no evidence that cooperation in both location and R&D decisions were perfectly correlated.

Through the resolution of the model, we intend to evaluate if firms' decision about location changes if they develop its R&D activities independently or in cooperation and benefit from different knowledge spillovers. We then proceed with a sketch of the model, which is presented in two scenarios - independent and cooperation in R&D - and present main results.

3.3 The Model

There are N identical firms that produce a homogeneous output, whose inverse demand function is given by

$$P = a - bQ \tag{3.1}$$

where Q is total output ($Q = \sum_{t=1}^{N} q_t$) ($a, b > 0$ and $Q \leq a/b$).

Each firm chooses its location in an open convex space M. As a result of location decisions, firms will benefit from a R&D spillover, $\beta(d_{rs})$, which is inversely related with d_{rs}, where $d_{rs} = d(r, s)$ is a measure of the physical distance between firms r and s $(r \neq s)$.

The spillover function is such that $0 \leq \beta(d_{rs}) \leq 1$ and $\beta'(d_{rs}) < 0$, that is, $\beta(d_{rs})$ is a positive and decreasing function of the distance d_{rs} between firms. For simplicity, we will denote it by $\beta_{rs} = \beta(d_{rs})$.

As it is typical in R&D cooperation models (e.g. d'Aspremont and Jacquemin [48]), we will assume that R&D output is cost reducing through an additive formulation, that is:

$$c_r = c - x_r - \sum_{t \neq r}^{N} \beta(d_{rt}) x_t \tag{3.2}$$

where c accounts for stand-alone marginal costs (identical to all firms) $(0 < c < a)$ and x_r measures firm r's R&D output. Additionally, it will be assumed that there are diminishing returns to R&D expenditures, that is, $C'(x_r) > 0$ and $C''(x_r) > 0$. In order to ensure positive quantities, we will impose $x_r + \sum_{t \neq r}^{N} \beta(d_{rt}) x_t \leq c$.

The profit of firm r is then given by:

$$\pi_r = (P - c_r) q_r - C(x_r) \tag{3.3}$$

As we focus on the geographical distance between firms and its impact on R&D activities through a spillover function, we will neglect the transport costs to the product market.

It is proposed a three-stage game, where firms decide about location, R&D and production. The timing is the following:

1^{st}) Firms choose its location in space M, from which results $d_{rt} \in \Re^{+}$ and $\beta_{rt} \in [0, 1]$;

2^{nd}) Firms simultaneously choose the level of R&D output, $x_r \in \Re^{+}$, independently or under cooperation;

3^{rd}) Firms simultaneously choose the level of output, $q_r \in \Re^+$, through Cournot competition.

For our purposes, we will assume $N = 3$ ($r = i, j, k$), whilst our results remain valid for a larger number of firms. Additionally, and as in d'Aspremont and Jacquemin [48], we will consider a specific functional form for the R&D cost function, $C(x_r) = 0.5\gamma x_r^2$.

The game will be solved by backward induction to ensure subgame perfectness and we will consider two alternative scenarios: *R&D Competition*, where firms choose its R&D output independently, and *R&D Cooperation*, where a subset of firms cooperate and coordinate R&D output in order to maximize joint profits.

3.3.1 Competition in R&D

Firm i's profit function is given by:

$$\pi_i \left(q, x, d\right) = \left(a - bQ - c_i\right) q_i - 0.5\gamma x_i^2 \tag{3.4}$$

where $q = \left(q_i, q_j, q_k\right), x = \left(x_i, x_j, x_k\right), d = \left(d_{ij}, d_{ik}, d_{jk}\right)$ and $c_i = c - x_i - \beta_{ij} x_j - \beta_{ik} x_k$. From the Cournot game it is straightforward to determine output equilibrium:

$$q^* = \frac{a - c + \left(3 - \beta_{ij} - \beta_{ik}\right) x_i + \left(3\beta_{ij} - \beta_{jk} - 1\right) x_j + \left(3\beta_{ik} - \beta_{jk} - 1\right) x_k}{4b} \tag{3.5}$$

and second-stage profit function comes:

$$\begin{aligned} \pi_i \left(q^*, x, d\right) \quad &= \quad \frac{1}{16b}(a - c + \left(3 - \beta_{ij} - \beta_{ik}\right) x_i + \left(3\beta_{ij} - \beta_{jk} - 1\right) x_j \\ &\quad + \left(3\beta_{ik} - \beta_{jk} - 1\right) x_k)^2 - 0.5\gamma x_i^2 \end{aligned} \tag{3.6}$$

After taking first-order condition and assuming that firms make a symmetric choice (that is, $x_i = x_j = x_k = x$), we may determine R&D output equilibrium ([12])([13]):

$$x^* = \frac{\left(3 - \beta_{ij} - \beta_{ik}\right)(a - c)}{8b\gamma - \left(3 - \beta_{ij} - \beta_{ik}\right)\left(2\beta_{ij} + 2\beta_{ik} - 2\beta_{jk} + 1\right)} \tag{3.7}$$

where $8b\gamma - \left(3 - \beta_{ij} - \beta_{ik}\right)\left(2\beta_{ij} + 2\beta_{ik} - 2\beta_{jk} + 1\right) > 0$ in order to ensure an interior and positive solution for R&D output and quantities[14].

Proposition 3.1 *When firms run R&D independently, there is a positive relationship between R&D output equilibrium and the physical distance between firms, if* $b\gamma > 2.25$.

Proof. Taking partial differentiation of R&D output to the physical distance between firms we get:

$$\frac{\partial x^*}{\partial \beta_{ij}} \frac{\partial \beta_{ij}}{\partial d_{ij}} = \frac{-(a-c)\left(8b\gamma - 2\left(3 - \beta_{ij} - \beta_{ik}\right)^2\right)}{\left(8b\gamma - \left(3 - \beta_{ij} - \beta_{ik}\right)\left(1 + 2\beta_{ij} + 2\beta_{ik} - 2\beta_{jk}\right)\right)^2} \beta'_{ij}$$

$$\frac{\partial x^*}{\partial \beta_{ik}} \frac{\partial \beta_{ik}}{\partial d_{ik}} = \frac{-(a-c)\left(8b\gamma - 2\left(3 - \beta_{ij} - \beta_{ik}\right)^2\right)}{\left(8b\gamma - \left(3 - \beta_{ij} - \beta_{ik}\right)\left(1 + 2\beta_{ij} + 2\beta_{ik} - 2\beta_{jk}\right)\right)^2} \beta'_{ik}$$

Given our assumptions, we have $\beta_{ij}, \beta_{ik}, \beta_{jk} \in [0, 1]$ and $\beta'_{ij} < 0$, $\beta'_{ik} < 0$. If we assume $8b\gamma - 2\left(3 - \beta_{ij} - \beta_{ik}\right)^2 > 0$ ([15]), then we will have $\partial x^*/\partial \beta_{ij} < 0$ and $\partial x^*/\partial \beta_{ik} < 0$. As a result, $\left(\partial x^*/\partial \beta_{ij}\right)\beta'_{ij} > 0$ and $(\partial x^*/\partial \beta_{ik})\beta'_{ik} > 0$. ■

This result accords with intuition: as the distance between firms increases, firms will perform a higher R&D output because a lower proportion of its R&D results will flow over the other firms. Two effects give reason to this result. On one side, the inverse relationship between firms' distance and R&D spillovers, $\partial \beta/\partial d < 0$, which derives from

[12] Second order condition implies $b\gamma > 9/8, \forall \beta_{ij}, \beta_{ik}, \beta_{jk} \in [0, 1]$.

[13] According to Henriques [91], it is necessary to set proper parameter restrictions for the existence and stability of equilibrium: $b\gamma > 15/8, \forall \beta_{ij}, \beta_{ik}, \beta_{jk} \in [0, 1]$.

[14] An interior solution is guaranteed for $b\gamma > 5/8, \forall \beta_{ij}, \beta_{ik}, \beta_{jk} \in [0, 1]$.

[15] This assumption only recquires that $b\gamma > 2.25, \forall \beta_{ij}, \beta_{ik}, \beta_{jk} \in [0, 1]$.

our assumptions and can be ascertained for instance, in Mai and Peng [133] and Long and Soubeyran [130]. On the other side, the well documented negative effect between R&D spillovers and R&D output, $\partial x/\partial\beta < 0$. In fact, several authors concluded that when firms run R&D independently, its R&D output (or expenditure) is higher for a lower R&D spillover. d'Aspremont and Soubeyran [48] concluded that, for the non-cooperative solution, R&D output decreases with R&D spillover. In an extensive survey on the topic of spillovers and R&D cooperation, Bondt [29] concluded that with low spillovers, Nash rivals are supposed to invest more in R&D than with high spillovers. Also, he concluded that positive and symmetric intra-industry spillovers tend to reduce the incentive for non-cooperative investments in R&D. Poyago and Theotoky [163] demonstrated that, if firms run R&D independently, the incentive to carry out R&D is greatly reduced in the presence of high R&D spillovers because the benefits of R&D are common to all firms.

First-stage profit function then becomes:

$$\pi_i\left(q^*, x^*, d\right) = \frac{0.5\gamma\left(a-c\right)^2\left(8b\gamma-\left(3-\beta_{ij}-\beta_{ik}\right)^2\right)}{\left(8b\gamma-\left(3-\beta_{ij}-\beta_{ik}\right)\left(1+2\beta_{ij}+2\beta_{ik}-2\beta_{jk}\right)\right)^2} \tag{3.8}$$

In the location game, we will focus on firms' best response for different R&D spillover's shapes, whilst spatial competition is leaved apart. For that purpose, we will consider the problem of a single firm i choosing its location in a convex space where firms j and k were located. So, firm i must choose d_{ij} and d_{ik}, given d_{jk}.

Formally, given other firms' location, firm i must choose its location subject to the following triangle inequality:

$$d_{ij} + d_{ik} \geq d_{jk}$$

Additionally, and as $d_{jk} \geq 0$, we must have:

$$d_{ik} \geq 0$$

$$d_{ij} \geq 0$$

Without loss of generality, we will impose:

$d_{ik} - d_{ij} \geq 0$

If we assume $d_{ik} - d_{ij} \geq 0$ and $d_{ij} \geq 0$, then $d_{ik} \geq 0$ is always true, and so, this constraint may be avoided.

Firm i will then solve the following problem:

$$\max_{d_{ij}, d_{ik} \in M} \pi_i (q^*, x^*, d)$$

$$s.t. \qquad g^1(d) = d_{ij} + d_{ik} - d_{jk} \geq 0$$

$$g^2(d) = d_{ik} - d_{ij} \geq 0$$

$$g^3(d) = d_{ij} \geq 0$$

The Lagrangean function corresponding to the maximization problem is then defined by:

$$L(d, \lambda) = \pi_i (q^*, x^*, d) + \lambda_1 (d_{ij} + d_{ik} - d_{jk}) + \lambda_2 (d_{ik} - d_{ij}) + \lambda_3 (d_{ij}) \tag{3.9}$$

where $\lambda = (\lambda_1, \lambda_2, \lambda_3)$ and $d = (d_{ij}, d_{ik}, d_{jk})$.

Through Kuhn-Tucker conditions, we have:

$$\frac{\partial L(d, \lambda)}{\partial d_{ij}} = \frac{\partial \pi_i^*}{\partial \beta_{ij}} \frac{\partial \beta_{ij}}{\partial d_{ij}} + \lambda_1 - \lambda_2 + \lambda_3 = 0 \tag{3.10}$$

$$\frac{\partial L(d, \lambda)}{\partial d_{ik}} = \frac{\partial \pi_i^*}{\partial \beta_{ik}} \frac{\partial \beta_{ik}}{\partial d_{ik}} + \lambda_1 + \lambda_2 = 0 \tag{3.11}$$

with $\lambda_1 \geq 0, \lambda_2 \geq 0, \lambda_3 \geq 0, g^1(d) \geq 0, g^2(d) \geq 0, g^3(d) \geq 0$ and $\lambda_1 (d_{ij} + d_{ik} - d_{jk}) = 0, \lambda_2 (d_{ik} - d_{ij}) = 0, \lambda_3 (d_{ij}) = 0$.

We now turn to first-stage profit function (3.8) and through simple arithmetic, we get partial differentiates of firm i's profit function with respect to its physical distance:

$$\frac{\partial \pi_i^*}{\partial \beta_{ij}} \frac{\partial \beta_{ij}}{\partial d_{ij}} = \frac{2\gamma (a-c)^2 \left(8b\gamma \left(4 - 2.5\beta_{ij} - 2.5\beta_{ik} + \beta_{jk}\right) - \left(3 - \beta_{ij} - \beta_{ik}\right)^3\right)}{\left(8b\gamma - \left(3 - \beta_{ij} - \beta_{ik}\right)\left(1 + 2\beta_{ij} + 2\beta_{ik} - 2\beta_{jk}\right)\right)^3} \beta'_{ij} \tag{3.12}$$

$$\frac{\partial\pi_i^*}{\partial\beta_{ik}}\frac{\partial\beta_{ik}}{\partial d_{ik}} = \frac{2\gamma\left(a-c\right)^2\left(8b\gamma\left(4-2.5\beta_{ij}-2.5\beta_{ik}+\beta_{jk}\right)-\left(3-\beta_{ij}-\beta_{ik}\right)^3\right)}{\left(8b\gamma-\left(3-\beta_{ij}-\beta_{ik}\right)\left(1+2\beta_{ij}+2\beta_{ik}-2\beta_{jk}\right)\right)^3}\beta'_{ik} \tag{3.13}$$

Given our assumptions, we have $\beta_{ij}, \beta_{ik}, \beta_{jk} \in [0,1]$ and $\beta'_{ij} < 0$, $\beta'_{ik} < 0$. Additionally, if we assume $8b\gamma\left(4-2.5\beta_{ij}-2.5\beta_{ik}+\beta_{jk}\right)-\left(3-\beta_{ij}-\beta_{ik}\right)^3 > 0$([16]), then $\left(\partial\pi_i^*/\partial\beta_{ij}\right)\beta'_{ij} < 0$ and $\left(\partial\pi_i^*/\partial\beta_{ik}\right)\beta'_{ik} < 0$([17]).

Allowing for different location choices, we will evaluate the best location choice for the entrant firm, assuming first, that the incumbent firms were agglomerated and second, that the incumbent firms were dispersed. We may then formulate the following propositions:

Proposition 3.2 *If two firms were close located and no cooperation is allowed, then the best location choice for an entrant firm is agglomeration, if* $\beta_{ij}+\beta_{ik} < 1.570$.

Proof. Assume $d_{jk} = 0$, that is, firms j and k are close located in space M. Under this scenario, we may have agglomeration $(d_{ij} = d_{ik} = 0)$ or dispersion $(d_{ij} = d_{ik} > 0)$. For $d_{ij} = d_{ik}$, then $\left(\partial\pi_i^*/\partial\beta_{ij}\right)\beta'_{ij} = \left(\partial\pi_i^*/\partial\beta_{ik}\right)\beta'_{ik} < 0$, and so, firm i will choose to be as close as possible to incumbent firms. ■

Example 3.1 *Suppose* $a = 100, b = 1, c = 50$ *and* $\gamma = 5$. *For simplicity, let's assume* $d_{ij}, d_{ik}, d_{jk} \in [0,1]$. *If firms* j *and* k *were close located, then* $d_{jk} = 0$ *and* $d_{ij} = d_{ik}$. *In this case, we could have agglomeration* $(d_{ij} = d_{ik} = 0)$ *or dispersion* $(d_{ij} = d_{ik} = 1)$. *Let's consider a linear spillover function,* $\beta(d) = 0.75(1-d)$, *whilst similar results would be gathered with different spillover functions. We then have* $\pi_i^*(d_{ij} = d_{ik} = 0) = 179.55 > \pi_i^*(d_{ij} = d_{ik} = 1) = 112.50$. *So, given that firms* j *and* k *were joint located, the best response for firm* i *is to join them.*

[16] We have $8b\gamma\left(4-2.5\beta_{ij}-2.5\beta_{ik}+\beta_{jk}\right)-\left(3-\beta_{ij}-\beta_{ik}\right)^3 > 0$ for $\beta_{ij}+\beta_{ik} < 1.570$, which accords with Amir [4], which imposed that for the consistency of the additive nature of the spillover process, we must have $\beta < \beta^{\max} = \left(\sqrt{n+1}\right)^{-1}$.

[17] Previous research on this topic confirms these results (e.g. Long and Soubeyran [130] established that $\partial\pi_i/\partial\beta_{ij} > 0$ and $\partial\pi_i/\partial\beta_{ik} > 0$).

Note that, as $d_{jk} = 0$ and $\beta'_{ij} = \beta'_{ik} < 0$, the entrant firm will always prefer to reduce its distance to both firms in order to benefit from maximal spillovers. But what will happen if the incumbent firms were dispersed?

Proposition 3.3 *If two firms were dispersed in a convex space M and no cooperation is allowed, then the best location choice for an entrant firm is in the straight-line between incumbent firms, if $\beta_{ij} + \beta_{ik} < 1.570$, that is:*

$$d_{ij} + d_{ik} = d_{jk}$$

Proof. Assume false, that is, suppose that firm i chooses to locate in the vertices of a triangle. In this case, $g^1(d)$ is non-binding and $\lambda_1 = 0$. Then, giving our assumptions, we may have one of the following situations: either (a) $d_{ik} = d_{ij}$ or (b) $d_{ik} > d_{ij}$.

(a) If $d_{ik} = d_{ij}$, $g^2(d)$ is binding and the remaining restrictions are non-binding. Then, Kuhn-Tucker conditions may be resumed to:

(3.10) $\left(\partial\pi_i^*/\partial\beta_{ij}\right)\beta'_{ij} = \lambda_2 \geq 0$

which is incompatible with (3.12), while

(3.11) $\left(\partial\pi_i^*/\partial\beta_{ik}\right)\beta'_{ik} = -\lambda_2 \leq 0$

is compatible with (3.13).

(b) If $d_{ik} > d_{ij}$, all restrictions are non-binding and Kuhn-Tucker conditions become:

(3.10) $\left(\partial\pi_i^*/\partial\beta_{ij}\right)\beta'_{ij} = 0$

(3.11) $\left(\partial\pi_i^*/\partial\beta_{ik}\right)\beta'_{ik} = 0$

which are incompatible with (3.12) and (3.13). ■

This proposition is quite intuitive: as the spillover is a decreasing function of the physical distance between firms, firm i will proceed to be as close as possible to both firms, and so, she will be located in the straight-line between them. The exact location will be sketch in the following proposition:

Proposition 3.4 *If two firms were dispersed in a convex space M and no cooperation is allowed, then the best location choice for an entrant firm depends on the shape of the spillover function, if $\beta_{ij} + \beta_{ik} < 1.570$:*

(i) If β is a strictly concave function of the distance between firms, then the entrant firm will be located exactly in between the incumbent firms;

(ii) If β is a linear function of the distance between firms, then any location along the straight line is possible;

(iii) If β is a strictly convex function of the distance between firms, then the entrant firm will choose to cluster with one of the firms or in between the incumbent firms.

Proof. From previous proposition, we have that $d_{ij} + d_{ik} = d_{jk}$. Then, we may have one of the following mutually exclusive locations:

(a) Firm i locates at the same local of firm j and away from firm k

In this case, $d_{ij} = 0$ ($\beta_{ik} = \beta_{jk} = \beta$), and so, $g^1(d)$ and $g^3(d)$ are binding. Kuhn-Tucker conditions then come:

(3.10) $(\partial\pi_i^*/\partial\beta_{ij})\beta'_{ij} = -\lambda_1 - \lambda_3 \leq 0$

(3.11) $(\partial\pi_i^*/\partial\beta_{ik})\beta'_{ik} = -\lambda_1 \leq 0$

which accord with (3.12) and (3.13). Additionally, through simple arithmetic manipulation of Kuhn-Tucker conditions, we have:

[(3.10)-(3.11)] $(\partial\pi_i^*/\partial\beta_{ij})\beta'_{ij} - (\partial\pi_i^*/\partial\beta_{ik})\beta'_{ik} = -\lambda_3 \leq 0$

which is compatible with

[(3.12)-(3.13)] $(\partial\pi_i^*/\partial\beta_{ij})\beta'_{ij} - (\partial\pi_i^*/\partial\beta_{ik})\beta'_{ik} = \frac{2\gamma(a-c)^2\left(8b\gamma\left(4-2.5\beta_{ij}-1.5\beta\right)-\left(3-\beta_{ij}-\beta\right)^3\right)\left(\beta'_{ij}-\beta'_{ik}\right)}{\left(8b\gamma-\left(3-\beta_{ij}-\beta_{ik}\right)\left(1+2\beta_{ij}+2\beta_{ik}-2\beta_{jk}\right)\right)^3}$

if and only if $\beta'_{ij} \leq \beta'_{ik}$, that is, for a convex or linear spillover function, given $d_{ik} > d_{ij} = 0$.

(b) Firm i locates along the straight line joining j and k but nearer to firm j

In this case, $0 < d_{ij} < d_{ik}$ and so, only $g^1(d)$ is binding. Kuhn-Tucker conditions then come:

(3.10) $(\partial\pi_i^*/\partial\beta_{ij})\beta'_{ij} = -\lambda_1 \leq 0$

(3.11) $(\partial\pi_i^*/\partial\beta_{ik})\beta'_{ik} = -\lambda_1 \leq 0$

which accord with (3.12) and (3.13). Additionally, through simple arithmetic manipulation of Kuhn-Tucker conditions, we have:

[(3.10)-(3.11)] $(\partial\pi_i^*/\partial\beta_{ij})\beta'_{ij} - (\partial\pi_i^*/\partial\beta_{ik})\beta'_{ik} = 0$

which is compatible with

[(3.12)-(3.13)] $(\partial\pi_i^*/\partial\beta_{ij})\beta'_{ij} - (\partial\pi_i^*/\partial\beta_{ik})\beta'_{ik} =$

$$= \frac{2\gamma(a-c)^2\left(8b\gamma\left(4-2.5\beta_{ij}-2.5\beta_{ik}+\beta_{jk}\right)-\left(3-\beta_{ij}-\beta_{ik}\right)^3\right)\left(\beta'_{ij}-\beta'_{ik}\right)}{\left(8b\gamma-\left(3-\beta_{ij}-\beta_{ik}\right)\left(1+2\beta_{ij}+2\beta_{ik}-2\beta_{jk}\right)\right)^3}$$

if and only if $\beta'_{ij} = \beta'_{ik}$, that is, for a linear spillover function, given $d_{ik} > d_{ij} > 0$.

(c) Firm i locates exactly at the middle point of the straight line joining j and k

In this case, $d_{ij} = d_{ik} > 0$ $(\beta_{ij} = \beta_{ik} = \beta)$,and so, $g^1(d)$ and $g^2(d)$ are binding. Kuhn-Tucker conditions then come:

(3.10) $(\partial\pi_i^*/\partial\beta_{ij})\beta'_{ij} = -\lambda_1 + \lambda_2$

(3.11) $(\partial\pi_i^*/\partial\beta_{ik})\beta'_{ik} = -\lambda_1 - \lambda_2 \leq 0$

which accord with (3.12) and (3.13). Additionally, through simple arithmetic manipulation of Kuhn-Tucker conditions, we have:

[(3.10)-(3.11)] $(\partial\pi_i^*/\partial\beta_{ij})\beta'_{ij} - (\partial\pi_i^*/\partial\beta_{ik})\beta'_{ik} = 0$

which is compatible with

[(3.12)-(3.13)] $(\partial\pi_i^*/\partial\beta_{ij})\beta'_{ij} - (\partial\pi_i^*/\partial\beta_{ik})\beta'_{ik} = \frac{2\gamma(a-c)^2\left(8b\gamma\left(4-5\beta+\beta_{jk}\right)-(3-2\beta)^3\right)\left(\beta'_{ij}-\beta'_{ik}\right)}{\left(8b\gamma-(3-2\beta)\left(1+4\beta-2\beta_{jk}\right)\right)^3}$

if $\beta'_{ij} = \beta'_{ik}$, that is, for any shape of the spillover function, given $d_{ij} = d_{ik}$ ■

Our results allow us to conclude that the entrant firm will always cluster with one of the firms if the R&D spillover is linear or convex in firms' physical distance, while for the case of a strictly concave spillover function, no clustering is observed, as the entrant firm chooses to stay in between the two incumbent firms. This conclusion is simply justified by the shape of the spillover function:

(i) If the spillover function is linear in distance, then it is indifferent for firm i to cluster or not with an incumbent firm, as any location yields the same total spillover effect (figure 3.1):

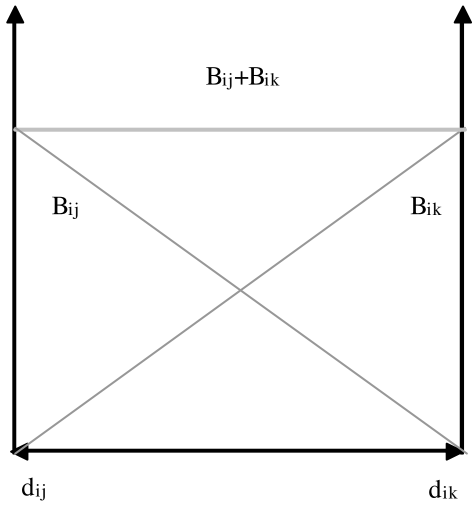

Figure 3.1. Firm i's total spillover with a linear spillover function

(ii) If the spillover function is concave, then locating at the middle point between the incumbent firms is the best choice as it yields the maximum total spillover for firm i (figure 3.2):

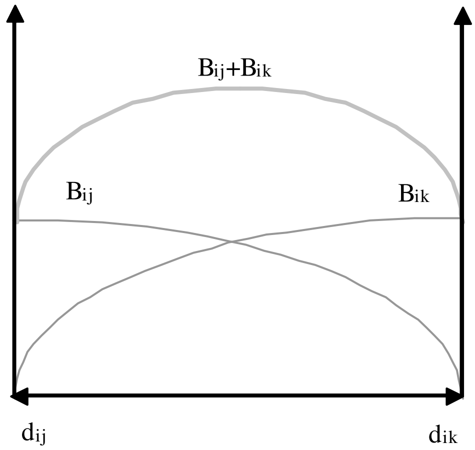

Figure 3.2. Firm i's total spillover with a concave spillover function

(iii) Finally, if the spillover function is convex, then clustering with one of the incumbent firms is the best choice, as it yields the maximum total spillover for firm i (figure 3.3):

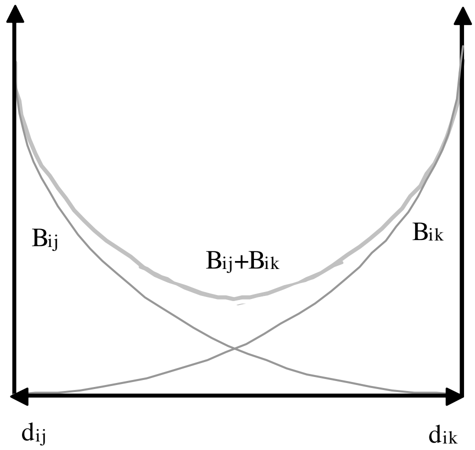

Figure 3.3. Firm i's total spillover with a convex spillover function

At last, let's make use of an example to fully clarify our proposition:

Example 3.2 *Assume* $a = 100, b = 1, c = 50$ *and* $\gamma = 5$. *For simplicity, let's assume* $d_{ij}, d_{ik}, d_{jk} \in [0, 1]$ *and* $d_{ij} + d_{ik} = d_{jk} = 1$. *In this case, we could have agglomeration* $(d_{ij} = 0; d_{ik} = 1)$ *or dispersion* $(d_{ij} = d_{ik} = 0.5)$. *We will have different choices for different shapes of the function:*

For a linear spillover function, $\beta(d) = 0.75(1-d)$*, agglomeration and dispersion are equivalent:* $\pi_i^*(d_{ij} = d_{ik} = 0.5) = \pi_i^*(d_{ij} = 0; d_{ik} = 1) = 184.79$

For a convex spillover function, $\beta(d) = 0.75\left(1-\sqrt{d}\right)$*, agglomeration is the best choice for firm* i*:* $\pi_i^*(d_{ij} = d_{ik} = 0.5) = 168.80 < \pi_i^*(d_{ij} = 0; d_{ik} = 1) = 184.79$

For a concave spillover function, $\beta(d) = 0.75(1-d^2)$*, dispersion is the best choice for firm* i*:* $\pi_i^*(d_{ij} = d_{ik} = 0.5) = 198.35 > \pi_i^*(d_{ij} = 0; d_{ik} = 1) = 184.79.$

So, from our results we were able to conclude that the best location' s strategy for an entrant firm depends on the shape of the spillover function: if the spillover function is linear or convex in firms' physical distance, then clustering is observed, while if the spillover function is strictly concave then no clustering emerged. Clearly, our conclusions are derived in a context where an entrant firm choose its location, given other firms' location.

Alternatively if we consider that all firms choose their locations sequentially, then the result will be an agglomeration equilibrium, whilst it would be gathered faster if the R&D spillover is convex in distance. In fact, if the spillover function is convex, then a sequential game implies that the first firm chooses its location, and after that all firms, sequentially, cluster with her. If the spillover function is concave, the entrant firm locates in between the other two firms, but sequentially, each other firm will locate in between the other firms. At the end, all firms will be agglomerated in a single point. Also, if we consider that all firms choose their locations simultaneously, then all of them anticipate that each other´s best response either is in the middle point location if the R&D spillover is concave, or to cluster if the R&D spillover is convex. In any case, but faster in the last case, the result will be an agglomeration equilibrium.

3.3.2 Cooperation in R&D

Cooperation in R&D may involve different dimensions and run through different design models. Typically, cooperation involves R&D cartelization, that is, the coordination of R&D expenditures in order to maximize joint profits. Most of the literature usually assumes industry-wide agreements (e.g., d'Aspremont and Jacquemin [48], Kamien, Muller and Zang [118], Suzumura [182] and Vonortas [194]), while others analyze cooperation within a subset of firms of a given industry (e.g., Poyago-Theotoky [163]). Frequently, the size of the R&D cartel is exogenous, whilst few papers aim at endogenize it (e.g., Katz [121] and Atallah [15]). Besides R&D cartelization, cooperating firms may jointly agree to internally raise the spillover parameter. In the limit, the sharing of R&D results could be set to its maximal value, a scenario described by Kamien, Muller and Zang [118] as cartelized RJV. Usually, the degree of information sharing between cooperating firms is assumed to be exogenous, while some articles aim at endogenize it (e.g., [120], Poyago-Theotoky [164], Piga and Poyago-Theotoky [161] and Amir, Evstigneev and Wooders [5]).

In this research, we will assume that a subset of firms cooperate and form a R&D cartel, whilst cooperation in the location decision or the production stage is never allowed. In our approach, R&D cooperation involves both R&D cartelization and increasing the information sharing between cooperating firms. Formally, this may be modelled through an increase of the spillover through a coefficient $\delta \geq 1$, where $\delta\beta \leq 1$. Throughout this approach, we intend to separate the effect of the location's decision (β) from the effect of the cooperation decision (δ) on total spillover, $\delta\beta$. Having in mind Kamien, Muller and Zang [118]'s typology, we will have, for the case of RJV cartelization, $\delta\beta = 1$, while for the R&D cartelization case, we will have $\delta = 1$ and $\delta\beta = \beta$.

Assume firms i and j decide to cooperate in R&D. Unit production costs then become:

$$c_i = c - x_i - \delta\beta_{ij}x_j - \beta_{ik}x_k$$

$$c_j = c - x_j - \delta\beta_{ij}x_i - \beta_{jk}x_k$$

$$c_k = c - x_k - \beta_{ik}x_i - \beta_{jk}x_j$$

where $\delta\beta_{ij} \leq 1$.

Firms' second-stage profit function then comes:

$$\pi_i(q^*,x,d) = \frac{1}{16b}(a-c+\left(3-\delta\beta_{ij}-\beta_{ik}\right)x_i + \left(3\delta\beta_{ij}-\beta_{jk}-1\right)x_j + \left(3\beta_{ik}-\beta_{jk}-1\right)x_k)^2 - 0.5\gamma x_i^2 \tag{3.14}$$

where $d=(d_{ij},d_{ik},d_{jk})$ and $x=(x_i,x_j,x_k)$.

In the R&D stage, cooperation implies that each firm within the R&D cartel will choose its R&D output in order to maximize joint profits, while non-cooperating firms will maximize individual profit:

$$\begin{aligned} &\partial\left[\pi_i(q^*,x,d)+\pi_j(q^*,x,d)\right]/\partial x_i = 0 \\ &\partial\left[\pi_k(q^*,x,d)\right]/\partial x_k = 0 \end{aligned} \tag{3.15}$$

Imposing symmetry between cooperating firms ($x_i = x_j = x$ = R&D output for a cooperating firm) and non-cooperating firms ($x_k = y$ = R&D output for a non-cooperating firm) and solving for x and y gives us R&D output equilibrium[18]:

$$x^* = [(a-c)\left(4b\gamma\left(1-\beta_{ik}+\delta\beta_{ij}\right) - \left(3-\beta_{ik}-\beta_{jk}\right)(\beta_{ik}^2-5\beta_{ik}+\delta\beta_{ij}\beta_{ik}+\beta_{ik}\beta_{jk}+\beta_{jk}+2\delta\beta_{ij}-3\delta\beta_{ij}\beta_{jk}+2)\right)]/[2b\gamma(8b\gamma-13+12\beta_{ik}+8\beta_{jk}-8\delta\beta_{ij}-4\beta_{ik}\beta_{jk}+6\delta\beta_{ij}\beta_{ik}+2\delta\beta_{ij}\beta_{jk}-3\beta_{ik}^2-\beta_{jk}^2-4\delta^2\beta_{ij}^2)+(-3+\beta_{ik}+\beta_{jk})(-\beta_{ik}^3-5\delta\beta_{ij}\beta_{ik}^2-2\beta_{ik}^2\beta_{jk}+7\beta_{ik}^2+2\beta_{ik}\beta_{jk}+4\delta^2\beta_{ij}^2\beta_{ik}+2\delta\beta_{ij}\beta_{ik}-4\delta^2\beta_{ij}^2\beta_{jk}+2\delta\beta_{ij}\beta_{ik}\beta_{jk}-\beta_{ik}\beta_{jk}^2+7\delta\beta_{ij}\beta_{jk}^2-2\delta^2\beta_{ij}^2-2+4\beta_{jk}-4\delta\beta_{ij}-5\beta_{jk}^2-2\beta_{ik})]$$

$$y^* = [2(a-c)\left(3-\beta_{ik}-\beta_{jk}\right)(b\gamma-\left(1-\beta_{ik}+\delta\beta_{ij}\right)\left(\delta\beta_{ij}-\beta_{jk}+1-\beta_{ik}\right))]/[2b\gamma(8b\gamma-13+12\beta_{ik}+8\beta_{jk}-8\delta\beta_{ij}-4\beta_{ik}\beta_{jk}+6\delta\beta_{ij}\beta_{ik}+2\delta\beta_{ij}\beta_{jk}-3\beta_{ik}^2-\beta_{jk}^2-4\delta^2\beta_{ij}^2)+(-3+\beta_{ik}+\beta_{jk})(-\beta_{ik}^3-5\delta\beta_{ij}\beta_{ik}^2-2\beta_{ik}^2\beta_{jk}+7\beta_{ik}^2+2\beta_{ik}\beta_{jk}+4\delta^2\beta_{ij}^2\beta_{ik}+2\delta\beta_{ij}\beta_{ik}-4\delta^2\beta_{ij}^2\beta_{jk}+2\delta\beta_{ij}\beta_{ik}\beta_{jk}-\beta_{ik}\beta_{jk}^2+7\delta\beta_{ij}\beta_{jk}^2-2\delta^2\beta_{ij}^2-2+4\beta_{jk}-4\delta\beta_{ij}-5\beta_{jk}^2-2\beta_{ik})]$$

[18] Second order condition recquires $b\gamma > 5/4, \forall\beta_{ij},\beta_{ik},\beta_{jk}\in[0,1]$ and $\delta\beta_{ij}\le 1$. Sufficient condition for the stability of equilibrium recquires $b\gamma > 5/2, \forall\beta_{ij},\beta_{ik},\beta_{jk}\in[0,1]$ and $\delta\beta_{ij}\le 1$ (Henriques [91]).

Literature usually refers that R&D output equilibrium for cooperating firms is higher than R&D output equilibrium for non-cooperating firms when R&D spillovers are high because in this case, it can avoid resources duplication (see, at this purpose, Katsoulacos and Ulph [120], Bondt and Henriques [30], Steurs [180] and Bondt [29]).

Simple simulations on R&D output equilibrium for cooperating and non-cooperating firms also confirms this conclusion (figures 3.4, 3.5 and 3.6).

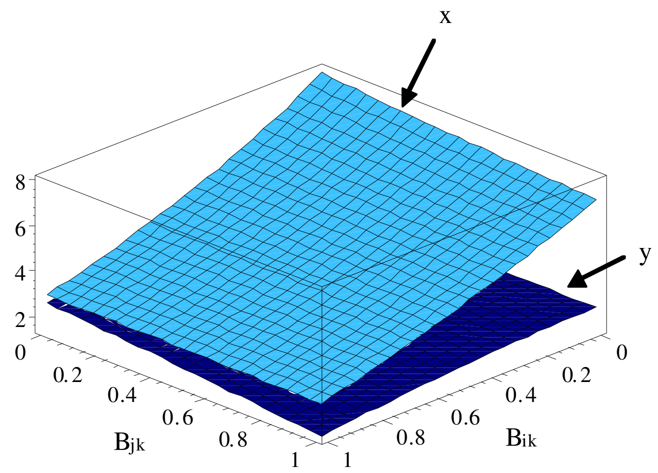

Figure 3.4. R&D output equilibrium for cooperating (x) and non-cooperating (y) firms when delta*Beta = 1

In fact, we have that for the RJV cartelization case $\left(\delta\beta_{ij} = 1\right)$, R&D output for cooperating firms is always higher than R&D output for non-cooperating firms. However, if there is no increasing of information sharing between cooperating firms ($\delta = 1$) and focusing on the clustering location $\left(d_{ij} = 0, d_{ik} = 1 \Rightarrow \beta_{ik} = \beta_{jk}\right)$ and on the dispersion location $\left(d_{ij} = d_{ik} > 0 \Rightarrow \beta_{ij} = \beta_{ik}\right)$, then R&D output equilibrium for cooperating firms is higher than R&D output equilibrium for non-cooperating firms only for high spillovers between cooperating firms.

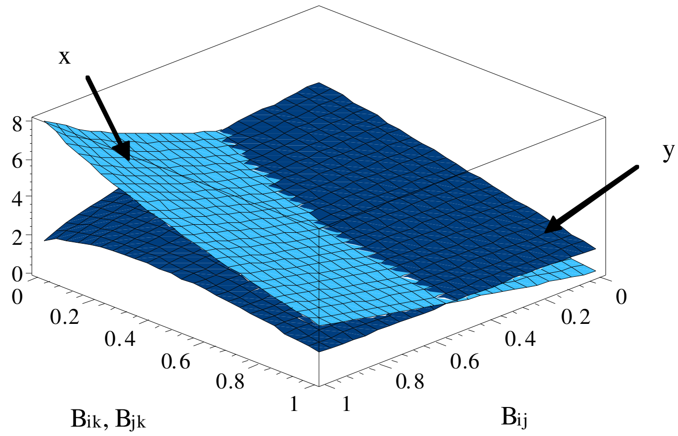

Figure 3.5. R&D output equilibrium for cooperating (x) and non-cooperating (y) firms when delta=1 and Beta(ik)=Beta(jk)

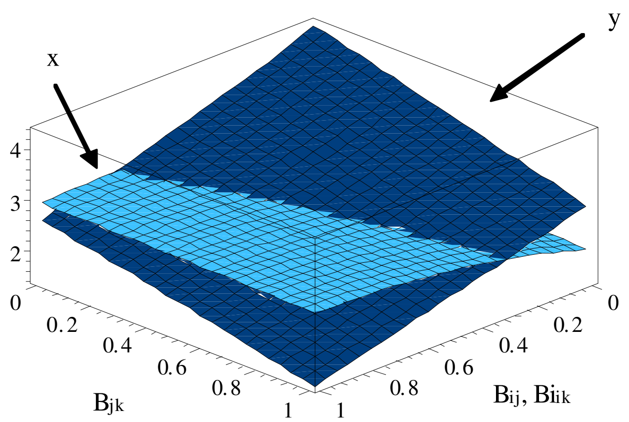

Figure 3.6. R&D output equilibrium for cooperating (x) and non-cooperating (y) firms when delta=1 and Beta(ij)=Beta(ik)

Let's now evaluate how R&D output is sensitive to the distance between firms.

Proposition 3.5 *When a subset of firms cooperate in R&D, its R&D output equilibrium will be higher for a higher degree of information sharing and for a lower physical distance between them, if* $b\gamma > 2.5238$.

Proof. Given our assumptions, we have $\beta_{ij}, \beta_{ik}, \beta_{jk} \in [0,1]$, $\beta'_{ij} < 0$, $\beta'_{ik} < 0$ and $\delta\beta_{ij} \leq 1$. Then, through simulation, we have that for $b\gamma > 2.5328$, $\partial x/\partial\delta = \partial x/\partial\beta_{ij} > 0$ and then $\left(\partial x/\partial\beta_{ij}\right)\beta'_{ij} < 0$. ■

These results are quite intuitive and find confirmation in related literature. In fact, and leaving apart the inverse relationship between firms' distance and R&D spillovers, the positive relationship between R&D output equilibrium and the spillover between cooperating firms is well documented in R&D texts. After evaluating different R&D design models, Kamien, Muller and Zang [118] found that R&D effective output is higher in the RJV cartelization case, where $\delta\beta = 1$, when comparing with simple R&D cartelization, where $\delta\beta = \beta$. Comparing a secretariat RJV ($\delta\beta = \beta$) with a operating RJV ($\delta\beta = 1$), Vonortas [194] concluded that the operating entity is more effective than the secretariat in improving firm's performance over the non-cooperative industry. Particularly, he observed that the operating entity members always invest more in R&D than the members of a secretariat, even when they both spend less than the non-cooperative case. Bondt [29] reached that cooperative R&D investments are typically stimulated by larger spillovers.

The following corollary completes previous proposition:

Corollary 3.1 *R&D output equilibrium for cooperating firms increases with the distance to non-cooperating firms, if* $b\gamma > 2.5328$.

Proof. Given our assumptions, we have $\beta_{ij}, \beta_{ik}, \beta_{jk} \in [0,1]$, $\beta'_{ij} < 0$, $\beta'_{ik} < 0, \beta'_{jk} < 0$ and $\delta\beta_{ij} \leq 1$. Then, through simulation, we have that for $b\gamma > 2.6768$, then $\left(\partial x/\partial\beta_{ik}\right)\beta'_{ik} > 0$. Similarly, for $b\gamma > 2.5328$, we have, through simulation, that $\left(\partial x/\partial\beta_{jk}\right)\beta'_{jk} > 0$. ■

So, when taking under consideration cooperating and non-cooperating firms, proposition 3.1 remains valid: there is a positive relationship between the R&D output and the distance between cooperating and non-cooperating firms. Additionally, we expect that R&D output equilibrium for non-cooperating firms increases with the distance to cooperating firms[19]. This behavior is justified by the need to avoid that R&D output spillovers to competing firms.

First-stage profit function then becomes:

$$\begin{aligned} \pi_i\left(q^*, x^*, y^*, d\right) &= \frac{1}{16b}(a - c + \left(2 + 2\delta\beta_{ij} - \beta_{ik} - \beta_{jk}\right) x^* + \\ &\left(3\beta_{ik} - \beta_{jk} - 1\right) y^*)^2 - 0.5\gamma\left(x^*\right)^2 \end{aligned} \tag{3.16}$$

where x^* and y^* are the R&D output for cooperating and non-cooperating firms, respectively.

In the location decision game, we will consider again the problem of a single firm i choosing its location in a delimited space where firms j and k were located. Note that cooperation is not allowed in the location stage, and so, the formulation of the problem is very similar to the independent case:

$$\begin{aligned} &\max_{d_{ij}, d_{ik} \in M} \pi_i\left(q^*, x^*, y^*, d\right) \\ s.t. \quad & g^1(d) = d_{ij} + d_{ik} - d_{jk} \geq 0 \\ & g^2(d) = d_{ik} - d_{ij} \geq 0 \\ & g^3(d) = d_{ij} \geq 0 \end{aligned}$$

Applying Kuhn-Tucker conditions to the Lagrangean function gives us similar expression to (3.10) and (3.11). Through tedious calculations, then, for $\beta_{ij}^{'} < 0$, $\beta_{ik}^{'} < 0$, $\beta_{ij}, \beta_{ik}, \beta_{jk} \in [0,1], \delta \geq 1$, $\delta\beta_{ij} \leq 1$, we have, though simulation that, for $b\gamma > 2.5328$:

$$\frac{\partial \pi^*}{\partial \beta_{ij}} \frac{\partial \beta_{ij}}{\partial d_{ij}} < 0 \tag{3.17}$$

$$\frac{\partial \pi^*}{\partial \beta_{ik}} \frac{\partial \beta_{ik}}{\partial d_{ik}} \gtreqless 0 \tag{3.18}$$

[19] As $\beta_{ij}, \beta_{ik}, \beta_{jk} \in [0,1]$ and $\delta\beta_{ij} \leq 1$, we have, through simulation, that for $b\gamma > 7.3241$, $\frac{\partial y}{\partial \beta_{jk}} \frac{\partial \beta_{jk}}{\partial d_{jk}} > 0$ and for $b\gamma > 10.476$, $\frac{\partial y}{\partial \beta_{ik}} \frac{\partial \beta_{ik}}{\partial d_{ik}} > 0$.

After evaluating different scenarios for location, we may conclude that the location choice when incumbent firms are agglomerate is invariant with a cooperative or competitive behavior in R&D:

Proposition 3.6 *If two firms were close located and cooperation in the R&D stage is allowed, then the best location choice for an entrant firm is agglomeration, if* $b\gamma > 2.5328$.

Proof. Assume $d_{jk} = 0$. Under this assumption, firm i have two hypothesis: either firm i chooses to locate near j and k $(d_{ij} = d_{ik} = 0)$ or firm i chooses to locate away from firms j and k $(d_{ij} = d_{ik} > 0)$.

(a) If $d_{ij} = d_{ik} = 0$ (agglomeration), then all restrictions are binding with the associated multipliers non negative. Kuhn-Tucker conditions then come:

(3.10) $(\partial \pi_i^* / \partial \beta_{ij}) \beta'_{ij} = -\lambda_1 + \lambda_2 - \lambda_3$

(3.11) $(\partial \pi_i^* / \partial \beta_{ik}) \beta'_{ik} = -\lambda_1 - \lambda_2 \leq 0$

which accord with (3.17) and (3.18) and confirms that agglomeration is an equilibrium.

(b) If $d_{ij} = d_{ik} > 0$ (dispersion), then only $g^2(d)$ is binding and Kuhn-Tucker conditions come:

(3.10) $(\partial \pi_i^* / \partial \beta_{ij}) \beta'_{ij} = \lambda_2 \geq 0$

which is incompatible with (3.17), while

(3.11) $(\partial \pi_i^* / \partial \beta_{ik}) \beta'_{ik} = -\lambda_2 \leq 0$

accords with (3.18. So, dispersion is not an equilibrium. ■

Next example will complement previous proposition:

Example 3.3 *Suppose* $a = 100, b = 1, c = 50$ *and* $\gamma = 5$. *For simplicity, let's assume* $d_{ij}, d_{ik}, d_{jk} \in [0, 1]$. *If firms* j *and* k *were close located, then* $d_{jk} = 0$ *and* $d_{ij} = d_{ik}$. *In this case, we could have agglomeration* $(d_{ij} = d_{ik} = 0)$ *or dispersion* $(d_{ij} = d_{ik} = 1)$.

As before, we consider a linear spillover function, $\beta(d) = 0.75(1-d)$, whilst similar results would be gathered with different spillover functions. We then have:

If firms do not increase the information sharing ($\delta = 1$), then

$\pi_i^* (d_{ij} = d_{ik} = 0) = 180.99 > \pi_i^* (d_{ij} = d_{ik} = 1) = 126.62$

If firms totally increase the information sharing between them ($\delta = 1/0.75$), then

$\pi_i^* (d_{ij} = d_{ik} = 0) = 192.91 > \pi_i^* (d_{ij} = d_{ik} = 1) = 126.62$

So, given that the incumbent firms were agglomerated, then the best location choice for the entrant-cooperating firm is to join them.

So, if two firms are joint located, the best response for a R&D cooperating firm is agglomeration. But whatever if they were geographically separated? As in the independent case, the best location choice for the entrant firm is in the straight-line between incumbent firms:

Proposition 3.7 *If two firms were dispersed in a convex space M and cooperation is allowed in the R&D stage, then the best location choice for an entrant firm is in the straight-line between incumbent firms, if $b\gamma > 2.5328$, that is,*

$$d_{ij} + d_{ik} = d_{jk}$$

Proof. Assume false, that is, suppose that firm i chooses to locate in the vertices of a triangle. In this case, $g^1(d)$ is non-binding. Then, we may have one of the following mutually exclusives situations:

(a) Firm i chooses to locate at the same distance to both firms ($d_{ij} = d_{ik}$). In this case, only $g^2(d)$ is binding and Kuhn-Tucker conditions are resumed to:

(3.10) $(\partial \pi_i^* / \partial \beta_{ij}) \beta'_{ij} = \lambda_2 \geq 0$

which is incompatible with (3.17), while

(3.11) $(\partial \pi_i^* / \partial \beta_{ik}) \beta'_{ik} = -\lambda_2 \leq 0$

accords with (3.18).

(b) Firm i chooses to locate closer to firm j $(d_{ij} > d_{ik})$. In this case, all restrictions are non-binding and Kuhn-Tucker conditions come:

(3.10) $(\partial\pi_i^*/\partial\beta_{ij})\beta_{ij}' = 0$

which is incompatible with (3.17), while

(3.11) $(\partial\pi_i^*/\partial\beta_{ik})\beta_{ik}' = 0$

accords with (3.18). ■

The exact location of the entrant-cooperating firm will be sketch in the following proposition:

Proposition 3.8 *If two firms intend to cooperate in R&D through joint profit maximization and increased information sharing, then clustering is always observed if* $b\gamma >$ *2.5328.*

Proof. Assume false, that is, assume firm i chooses to locate exactly in between firms j and k so that $d_{ij} = d_{ik}$, whilst $d_{ij} + d_{ik} = d_{jk} > 0$. Then Kuhn Tucker conditions are resumed to:

(3.10) $(\partial\pi_i^*/\partial\beta_{ij})\beta_{ij}' = -\lambda_1 + \lambda_2$

(3.11) $(\partial\pi_i^*/\partial\beta_{ik})\beta_{ik}' = -\lambda_1 - \lambda_2 \leq 0$

which accord with (3.17) and (3.18). However, through simple calculations, we have,

[(3.10) - (3.11)] $(\partial\pi_i^*/\partial\beta_{ij})\beta_{ij}' - (\partial\pi_i^*/\partial\beta_{ik})\beta_{ik}' = 2\lambda_2 \geq 0$

Having in mind that $\beta_{ij}, \beta_{ik}, \beta_{jk} \in [0, 1]$ and assuming $b\gamma > 2.5328$, we have that, for $\delta > 1$, $\delta\beta_{ij} \leq 1$ and so,

[(3.17) - (3.18)] $(\partial\pi_i^*/\partial\beta_{ij})\beta_{ij}' - (\partial\pi_i^*/\partial\beta_{ik})\beta_{ik}' < 0$

which contradicts Kuhn-Tucker conditions. ■

As it was expected, R&D cooperation affects firms' decision about location: if there is an increasing information sharing between firms and joint profit maximization, then the entrant-cooperating firm always prefer to locate near the incumbent-cooperating firm for every shape of the spillover function, and so, clustering is a immediate result from cooperation. However, to achieve this result it is required an increasing information sharing between firms. In fact, if we assume $\delta = 1$, then $\left(\partial\pi_i^*/\partial\beta_{ij}\right) - \left(\partial\pi_i^*/\partial\beta_{ik}\right) \gtreqless 0$, and so, we can not eliminate the middle point location. Next example will help us to fully clarify our proposition:

Example 3.4 *Assume $a = 100, b = 1, c = 50$ and $\gamma = 5$. For simplicity, let's assume $d_{ij}, d_{ik}, d_{jk} \in [0,1]$ and $d_{ij} + d_{ik} = d_{jk} = 1$. In this case, we could have agglomeration $(d_{ij} = 0; d_{ik} = 1)$ or dispersion $(d_{ij} = d_{ik} = 0.5)$.*

For a linear spillover function, $\beta(d) = 0.75(1-d)$, agglomeration is the best choice for firm i :

R&D cartel $(\delta = 1) : \pi_i^*\left(d_{ij} = d_{ik} = 0.5\right) = 184.44 < \pi_i^*\left(d_{ij} = 0; d_{ik} = 1\right) = 200.51$

RJV cartel $(\delta\beta = 1) : \pi_i^*\left(d_{ij} = d_{ik} = 0.5\right) = 233.3 < \pi_i^*\left(d_{ij} = 0; d_{ik} = 1\right) = 242.71$

For a convex spillover function, $\beta(d) = 0.75\left(1-\sqrt{d}\right)$, agglomeration is also the best choice for firm i:

R&D cartel $(\delta = 1) : \pi_i^*\left(d_{ij} = d_{ik} = 0.5\right) = 168.72 < \pi_i^*\left(d_{ij} = 0; d_{ik} = 1\right) = 200.51$

RJV cartel $(\delta\beta = 1) : \pi_i^*\left(d_{ij} = d_{ik} = 0.5\right) = 234.09 < \pi_i^*\left(d_{ij} = 0; d_{ik} = 1\right) = 242.71$

For a concave spillover function, $\beta(d) = 0.75(1-d^2)$, agglomeration is the best choice for firm i if there is an increasing information sharing between cooperating firms:

R&D cartel $(\delta = 1) : \pi_i^*\left(d_{ij} = d_{ik} = 0.5\right) = 201.9 > \pi_i^*\left(d_{ij} = 0; d_{ik} = 1\right) = 200.51$

R&D cartel $(\delta = 1.1) : \pi_i^*\left(d_{ij} = d_{ik} = 0.5\right) = 205.06 < \pi_i^*\left(d_{ij} = 0; d_{ik} = 1\right) = 211.03$

RJV cartel $(\delta\beta = 1) : \pi_i^*\left(d_{ij} = d_{ik} = 0.5\right) = 234.25 < \pi_i^*\left(d_{ij} = 0; d_{ik} = 1\right) = 242.71$

3.4 Concluding remarks

Empirical research usually confirms the strong propensity for the clustering of innovative related activities, which is commonly justified by the existence of knowledge spillovers. Additionally, proximity is frequently cited as an explanation for the emergence of cooperative behaviors among firms or between firms and others interfaces (e.g. Universities).

Inspired in several empirical results, we intended to evaluate if firms' decision about location revises wether firms cooperate or compete in R&D. Through a simple game between three firms, from which two of them intend to cooperate in R&D, it was possible to conclude that the clustering of firms is always true if firms run R&D cooperatively. In fact, we demonstrated that if R&D runs independently, the entrant firm will cluster if the R&D spillover function is convex in the physical distance between firms. On the other hand, if R&D runs cooperatively between the entrant and an incumbent firm, then the entrant firm will always prefer to stay close to the cooperating-incumbent firm if there is an increasing information sharing among them. In any case, if the two incumbent firms were close located, agglomeration is always observed.

Our results also concern about R&D output equilibrium. We demonstrated that if R&D runs independently, then R&D equilibrium output is larger as the distance between firms increases. The intuition is simple: as the distance between firms increases, firms will perform an higher R&D output because a lower proportion of its results will flow over the other firms. However, if R&D runs cooperatively, then R&D equilibrium output for cooperating firms increases with the degree of information sharing between them, as well as with the reduction of the distance between cooperative firms. On the other hand, it reduces when the distance from cooperative firms to non-cooperative firms is shorter. With respect to R&D equilibrium output for non-cooperating firms, results were similar to the independent case.

Research on the topic of location choice and R&D cooperation may proceed in several directions. One possible line of research is to introduce uncertainty with respect to the R&D output (e.g. Choi [40], Combs [44] and Hauenschild [86]), which might affect firms' decision about location and R&D cooperation. Another research topic concerns with the consideration of firms' absorptive capacity (e.g. Kamien and Zang [119]), which might affect firm's decision about location and R&D cooperation. Finally, research may also proceed with an evaluation of the implications of R&D policies for the location choice and R&D cooperation (e.g. Hinlopen [92] and Leahy and Neary [127]).

Chapter 4

A Spatial Competition Model with R&D Cooperation

4.1 Introduction

Empirical research usually supports the hypothesis that knowledge spillovers have a positive influence on the location and agglomeration of firms (e.g. Jaffe, Trajtenberg and Henderson [116], Feldman [56], Carrincazeaux, Lung and Ralle [35] and Verspargen and Schoenmakers [191]). Furthermore, the emergence of cooperative behaviors among competing firms and its relation with knowledge spillovers is also evidenced (e.g. Cassiman and Veugelers [36], Belderbos *et al* [24] and Fritsch and Franke [63]).

This research aims at evaluating if spatial competition between competing firms affects its decision about location and R&D cooperation. For that purpose, we developed a strategic interaction game between two firms to assess if its location choice affects its decision to cooperate or compete in R&D. We assumed that firms benefit from a knowledge spillover if they were agglomerated, while if firms were dispersed, no spillover will occur. Also, firms must decide to cooperate or compete in R&D. Additionally, if firms cooperate in R&D, they must decide about the amount of know-how to disclose to the research joint project, which is uncertain if firms are dispersed. Finally, firms are allowed to sell its product in both internal and external market, having under consideration positive transport costs between regions.

The resolution of the model allows us to conclude that, for sufficiently high transport costs, firms prefer to disperse between regions and cooperate in R&D in order to overcome the absence of spillovers. Accordingly, if transport costs are low, firms will agglomerate if the probability of disclosing information is low, while if this probability is high, then cooperating firms will disperse and thus lessen the weight of transport costs.

The remainder of the chapter is organized as follows. We start with a brief overview of the literature on spatial competition and knowledge spillovers. Next, we proceed with a description of the model, which is developed under two scenarios - agglomeration and dispersion - and investigate how firms' decision about location and R&D cooperation were related. The final section concludes the chapter.

4.2 Related literature

Since the seminal paper of Hotelling [98], a large and rich literature on spatial competition has emerged. Usually, location models are classified into shopping or shipping models. A *shopping model* (or a *mill pricing* model) assumes that consumers bear the transport costs (e.g. Hotelling [98]), while a *shipping model* (or *delivered price* model) assumes that firms deliver the product and pay for the transport costs (e.g. Hoover [97] and Greenhut and Greenhut [72]). According to Fujita and Thisse [65], shopping models seem to be appropriate to study competition between sellers of consumption goods, while shipping models would describe better competition between sellers of industrial goods. Though with different aims, both models have the same centrifugal and centripetal forces, thus leading to similar location patterns under similar assumptions.

Spatial competition models may also encompass either Bertrand or Cournot competition[20]. Most literature deals with price competition and finds their roots in Hotelling [98]'s model, who assumed that consumers have an inelastic demand and are uniformly distributed along a bounded linear market. He then concluded that the only Nash equilibrium for the duopolists with a linear transport cost function is at the centre of the market. This result, known as the *Principle of Minimum Differentiation*, has been criticized and extended since its publication. For instance, d'Aspremont, Gabzewics and Thisse [47] demonstrated that agglomeration intensifies price competition between firms, which drives profits to zero. As a result, firms will choose to maximize their spatial differentiation in order to obtain positive profits. Eaton and Lipsey [55] examined the conditions under which the *Principle of Minimum Differentiation* was valid and concluded for its corroboration only for the duopoly case and if firms pursue a strategy of zero conjectural variation. Even if assuming uneven consumers distribution (e.g. triangular markets) and simultaneous or sequential firms entry, no agglomeration equilibria is obtained (e.g. Tabuchi and Thisse [183] and Tsai and Lai [186]).

Under Bertrand competition, agglomeration only occurs if an additional differentiation dimension is allowed. De Palma *et al* [49] restores the principle of minimum differentiation by assuming enough heterogeneity in consumers' tastes. Ben-Akiva, De Palma and Thisse [27] assumed different brand specifications, besides location differentiation, and concluded that firms agglomerate at the market centre when product differentiation is large enough. Also, Friedman and Thisse [62] demonstrated that if partial price collusion is allowed, then there is a unique location equilibrium that involves firms agglomeration. Assuming that consumers maximize a random utility function, Anderson, De Palma and Thisse [7] demonstrated that firms agglomerate at the market centre when price competition is weaken by sufficient heterogeneity in products/consumers. Recently, information

[20] According to Gupta, Pal and Sarkar [83], studying Cournot or Bertrand competition depends largely on the nature of the product. For instance, price competition is more likely when products are highly advertised, while quantity competition is more likely in the case of heavy manufacturing.

asymmetry or incomplete information have also been introduced as an explanation for spatial agglomeration under price competition (e.g. Tropeano [185], Valletti [188] and Christou and Vettas [42]).

A relatively smaller body of literature deals with Cournot competition and location games and usually predicts that an agglomeration equilibria exists if population density is sufficiently important[21]. Pioneering contributes are due to Greenhut and Greenhut [72] and Norman [146], who assumed that firms behave as Cournot oligopolists and discriminate over space. However, these authors were mainly concerned with the pattern of equilibrium prices resulting from Cournot competition and treated location as a non-strategic variable.

A more recent approach, launched by Hamilton, Thisse and Weskamp [84] and Anderson and Neven [8], focus on the study of spatial Cournot competition with endogenous location choice. They considered a location-quantity game in the traditional Hotelling's linear city model, with a linear demand and linear transportation costs. Hamilton, Thisse and Weskamp [84] considered a duopoly and compared the outcomes of Bertrand and Cournot competition, while Anderson and Neven [8] generalized for n-firms. They both concluded that Cournot competition yields firms agglomeration.

Gupta, Pal and Sarkar [83] extended Anderson and Neven's [8] research by allowing for non-uniform consumer distributions along the interval [0, 1]. They established the robustness of the agglomeration equilibria for a broad class of consumer density functions, concluding that (i) agglomeration of all n firms is an equilibrium and (ii) agglomeration of duopolists is the only equilibrium. Also, Mayer [140] allowed the production costs to differ across various locations, and concluded that agglomeration still emerges if production cost are convex (or minimum at the center), while if production costs are concave, then agglomeration is not observed.

Most work in spatial competition literature is based on the linear city model, while few analyze endogenous location in Salop's [170] circular city. Adopting an uniform dis-

[21] According to Gupta *et al* [82], this result accords with empirical studies. So, the predictions arising from a spatial Cournot model often describe the real world better than those arising from a spatial price competition model.

tribution of consumers along a circular city, Pal [155] demonstrated that both Bertrand and Cournot competition yield dispersed and identical equilibrium location: firms locate equidistant from each other on the circle so that total transportation cost are minimum. Matsushima [139] also analyzed the location and quantity choice in a circular city and demonstrated that firms may agglomerate at two points in a circular city, which differ from Pal's equidistant location pattern. In a subsequent paper, Gupta *et al* [82] demonstrated that both agglomeration and dispersion location equilibria might emerge in a circular city. They have identified several equilibria, which predict either an equidistant, non-equidistant, multiple or a continuum of locations. They have also demonstrated that agglomeration equilibrium only involves a subset of firms, which contrast with the existing literature. Also, Matsumura, Ohkawa and Shimizu [138] introduced non-linear transport costs and demonstrated that Pal's dispersion equilibria is more robust than Matsushima's partial agglomeration equilibria, as the first holds for any transport cost functions while the later only holds for a linear transport cost.

4.3 Motivation

Over the recent years, a significant body of literature has emphasized the importance of the exchange of information among firms (e.g. Becattini [23], Porter [162]). Particularly, several researchers claim for the localized character of the diffusion of knowledge (e.g. Jaffe, Trajtenberg and Henderson [116], Audretsch and Feldman [16] and Feldman [56], among others).

In this chapter, we intend to develop a model of spatial competition *à la* Hotelling that incorporates knowledge spillovers as a centripetal force. Inspiration was found in the work of Belleflame, Picard and Thisse [26], who considered an oligopoly where firms producing a differentiated product decide to locate in two possible regions and then compete in prices. They have also assumed that firms benefit from localization economies that depend on the number of firms that are co-located. Another relevant paper is Soubeyran and Weber [178], who extended previous work by considering an arbitrary number of regions, strategic interaction captured by Cournot competition and heterogeneity of firms transportation and production costs. Both articles generally support the relevance of localization economies as transport costs between regions fall.

Recently, spatial competition models have been extended to capture knowledge spillovers that are R&D specific. It was the case of Mai and Peng [133], who presented a model of spatial competition *à la* Hotelling that introduces an element of tacit cooperation between firms through information exchanges that are distance-sensitive. Additionally, Piga and Poyago-Theotoky [161] developed a three-stage duopoly model where firms choose location, quality-enhancing R&D and price under the assumption that R&D spillovers depend on firms' geographical distance. They demonstrated that the higher the degree of product differentiation (or alternatively, the higher the transportation costs), the higher is the distance between firms and the R&D effort.

We intend to improve previous research by explicitly considering that firms engage in either R&D cooperation or competition. Our purpose is to evaluate if firms decision about cooperation or competition in R&D are affected by firms' location choice in the context of spatial competition and knowledge spillovers. To our knowledge, although some authors focus on spatial competition between firms under R&D spillovers, no attempts have been made to explicitly introduce a R&D cooperation decision.

This research will merge R&D cooperation models into a spatial competition framework, which are typically disconnected in literature. As we have already seen in the previous chapter, R&D models are built by means of an oligopoly model in which firms make their R&D decision in a first pre-competitive stage and their quantity/price setting in a second stage. The most prominent works are d'Aspremont and Jacquemin [48] and Kamien, Muller and Zang [118], who proposed R&D cartelization under either R&D output or R&D expenditures spillovers. Since these starting articles, a lot of scientific models emerged around the topic of R&D cooperation, providing numerous extensions to those pioneering articles. Particularly relevant for our research are the extensions that assume uncertainty with respect to the success of a R&D project (e.g. Choi [40], Combs [44]) and that consider asymmetries with respect to the disclosure effort (Pérez-Castrillo and Sandonís [159], Rosenkranz [169] and Pastor and Sandonís [158]).

The model we developed is then related to Belleflame, Picard and Thisse [26] and Piga and Poyago-Theotoky [161] but we explicitly introduce a R&D stage where firms decide to cooperate or compete in R&D and choose its know-how disclosure. More precisely, we develop a three stage game between two firms, where each firm decides about location, R&D expenditures and afterwards engage in Cournot competition. In the location game, firms simultaneously decide about to locate in two symmetric regions. If both firms locate in the same region (agglomeration), then they will benefit from a positive R&D spillover, but if firms locate in different regions (dispersion), the R&D spillover will be zero. In the R&D stage, firms must decide about its cost-reducing R&D output, independently or under cooperation. Additionally, if firms cooperate in R&D, they must also decide about the amount of know-how to disclose to the research joint project. Moreover, we will assume that if firms locate in the same region, the disclosure effort is symmetric and observable, whilst if firms disperse, they face uncertainty with respect to its rival' disclosure effort. In the last stage, firms will decide about the quantities to sell in both regions, having under consideration positive transport costs between regions.

4.4 The Model

We consider an economy with two firms, 1 and 2, producing a homogenous product. Both firms decide first to locate in either two possible regions, A and B. Afterwards, they will decide to cooperate or compete in R&D and finally they will choose its quantities non-cooperatively. Both regions are characterized by the same market conditions. We also assume that markets are segmented, that is, each firm sets a quantity specific to the market in which its product is sold. More precisely, the inverse demand functions in each market are:

$$P_A = a - bQ_A$$

$$P_B = a - bQ_B$$

where $Q_A = q_{1A} + q_{2A}$ and $Q_B = q_{1B} + q_{2B}$.

Firms engage in R&D in order to reduce its production costs. Further, the R&D undertaken by one firm may benefit its rival at no cost if firms locate in the same region. Additionally, the R&D spillover, denoted by β, could be increased if firms cooperate in R&D and voluntarily share its know-how. However, uncertainty emerges if firms locate in different regions, as in this case, firms are uncertain about its rival's disclosure effort.

As it is typical in R&D cooperation models, we will assume that the R&D output is cost reducing through an additive formulation, that is:

$$c_i = c - x_i - \beta x_j$$

where c accounts for stand-alone marginal costs (identical to all firms) $(0 < c < a)$ and x_i measures firm i's R&D output $(i = 1, 2)$. Additionally, it will be assumed that there are diminishing returns to R&D expenditures, that is, $C'(x_i) > 0$ and $C''(x_i) > 0$. In order to ensure positive quantities, we will impose $x_i + \beta x_j \leq c$. Also, and in order to guarantee the existence of equilibrium, we will assume quadratic R&D costs, $C(x_i) = \gamma (x_i)^2 /2$, as in d'Aspremont and Jacquemin [48].

Each firm's profit function then comes $(i = 1, 2)$:

$$\pi_i = (P_A - c_{iA})\, q_{iA} + (P_B - c_{iB})\, q_{iB} - \gamma (x_i)^2 /2$$

In order to export its product, each firm has to incur in a constant unit transport cost from one region to the other, which is given by $t > 0$.

The timing of the game is the following:

(i) In the first stage, firms simultaneously decide about its location in two symmetric regions, A and B. If firms agglomerate, they will both benefit from a positive and symmetric R&D spillover, $\beta \in (0, 1)$; if firms disperse, no spillover will occur.

(ii) In the second stage, firms simultaneously decide about its cost-reducing R&D, independently or under cooperation. Additionally, if firms cooperate in R&D, they must also decide about the amount of know-how to disclose to the R&D cartel, δ_i $(i = 1, 2)$, which is uncertain if firms locate in different regions. For simplicity, we will focus on two extreme scenarios: either firms do not disclose any information to the R&D cartel $(\delta_i = 0)$ (R&D cartel) or they will totally disclose its information $(\delta_i = 1 - \beta)$ (Research Joint Venture (RJV)).

(iii) In the last stage, firms compete in quantities.

The game will be solved by backward induction for its subgame perfect Nash equilibria. We start by solving the last stage of the game where four subgames must be considered according to wether firms are agglomerated or not and wether firms cooperate or nor in R&D.

4.5 Agglomeration

Assume both firms locate in the same region. As regions are symmetric, we will assume, without loss of generality, that firms choose to locate in region A and export to region B. We then have:

$$\begin{aligned} \pi_1 &= (a - bQ_A - c + x_1 + (\beta + \delta_2) x_2) q_{1A} + \\ &\quad (a - bQ_B - c - t + x_1 + (\beta + \delta_2) x_2) q_{1B} - \gamma (x_1)^2 / 2 \\ \pi_2 &= (a - bQ_A - c + x_2 + (\beta + \delta_1) x_1) q_{2A} + \\ &\quad (a - bQ_B - c - t + x_2 + (\beta + \delta_1) x_1) q_{2B} - \gamma (x_2)^2 / 2 \end{aligned} \tag{4.1}$$

4.5.1 Firms' behavior in the product market

Taking first order conditions from (4.1) and solving for the equilibrium quantities:

$$\begin{aligned}
q_{1A} &= (a-c+(2-\delta_1-\beta)\,x_1+(2\beta+2\delta_2-1)\,x_2)\,/3b \qquad (4.2)\\
q_{1B} &= (a-c-t+(2-\delta_1-\beta)\,x_1+(2\beta+2\delta_2-1)\,x_2)\,/3b\\
q_{2A} &= (a-c+(2\beta+2\delta_1-1)\,x_1+(2-\beta-\delta_2)\,x_2)\,/3b\\
q_{2B} &= (a-c-t+(2\beta+2\delta_1-1)\,x_1+(2-\beta-\delta_2)\,x_2)\,/3b
\end{aligned}$$

If firms agglomerate, then in the second stage profit functions will be:

$$\begin{aligned}
\pi_1 &= ((a-c+(2-\delta_1-\beta)\,x_1+(2\beta+2\delta_2-1)\,x_2)^2+ \qquad (4.3)\\
&\quad (a-c-t+(2-\delta_1-\beta)\,x_1+(2\beta+2\delta_2-1)\,x_2)^2)/9b-\gamma\,(x_1)^2\,/2\\
\pi_2 &= ((a-c+(2\beta+2\delta_1-1)\,x_1+(2-\beta-\delta_2)\,x_2)^2+\\
&\quad (a-c-t+(2\beta+2\delta_1-1)\,x_1+(2-\beta-\delta_2)\,x_2)^2)/9b-\gamma\,(x_2)^2\,/2
\end{aligned}$$

4.5.2 R&D decision

4.5.2.1 R&D competition

If firms do not join the R&D cartel, they will carry out independent R&D and no disclosure of information will occur, that is, $\delta_1 = \delta_2 = 0$ and they will maximize individual profit functions. Taking first order conditions from (4.3) and solving for R&D output:

$$x_1 = x_2 = \frac{-2\,(2\,(a-c)-t)\,(\beta-2)}{9b\gamma-4\beta+4\beta^2-8} \qquad (4.4)$$

In order to have positive quantities, we must impose $t < 2(a-c)$ (for $b\gamma > 4/3$). If firms agglomerate in one region (A) and compete in R&D (N), then its profit will be[22]:

$$\begin{aligned}\pi^{AN} = & [9\gamma b(2(a-c)(a-c-t)\left(9b\gamma - 4\beta^2 - 16 + 16\beta\right) \\ & + t^2\left(9b\gamma - 16 + 4\beta + 2\beta^2\right)) + 8t^2(1+\beta)^2(\beta-2)^2] \\ & /[9b\left(4\beta^2 - 4\beta - 8 + 9b\gamma\right)^2]\end{aligned} \tag{4.5}$$

4.5.2.2 R&D cooperation

Even if being competitors in the product market, firms may benefit from R&D cooperation. Under perfect information, firms will decide both about a cost-reducing R&D through profit cartelization and about the amount of know-how to disclose to the R&D cartel, δ_i, so that $\delta_i + \beta \leq 1$.

For our purpose, we will assume that under agglomeration, firms have perfect information about the know-how its partner discloses to the joint research. In fact, and as it is typical in R&D cooperation literature (e.g. d'Aspremont and Jacquemin [48] and Kamien, Muller and Zang [118]), we will assume that the disclosure effort is observable and contractible[23]. Additionally, we will consider two disclosure efforts: either firms do not disclose any information to the research joint project, $\delta_1 = \delta_2 = 0$ (R&D cartel) or they both disclose its maximum know-how, $\delta_1 = \delta_2 = 1 - \beta$ (RJV).

The R&D decision will then result from the following maximization problem:

$$\underset{x_1,x_2}{Max}\ \Pi = \pi_1(\delta_1 = \delta_2 = \delta) + \pi_2(\delta_1 = \delta_2 = \delta) \tag{4.6}$$

[22]Second order condition for profit maximization implies $\partial^2\pi_i/\partial x_i^2 < 0$, which is true for $b\gamma > 16/9, \forall\beta \in (0,1)$.

[23]Recently, some papers introduced asymmetries with respect to the disclosure effort. Pérez-Castrillo and Sandonís [159] assumed that there is a moral hazard problem concerning the disclosure effort. They have show that under certain circumstances, a profitable RJV do not start when the disclosure of know-how is not contractible, and characterize the incentive contracts when they exists. In particular, they have show that the inclusion of penalties can be a way of alleviating the incentive problem or the individual rationality constraints. Moreover, they have also showed that a RJV can be an alternative to licensing contracts for the transmission of know-how.

where

$$\begin{aligned}\Pi &= \frac{1}{9b}(((a-c)+(2-\delta-\beta)x_1+(2\beta+2\delta-1)x_2)^2 \\ &\quad +((a-c)-t+(2-\delta-\beta)x_1+(2\beta+2\delta-1)x_2)^2 \\ &\quad +((a-c)+(2\beta+2\delta-1)x_1+(2-\beta-\delta)x_2)^2 \\ &\quad +((a-c)-t+(2\beta+2\delta-1)x_1+(2-\beta-\delta)x_2)^2) \\ &\quad -\gamma(x_1)^2/2-\gamma(x_2)^2/2\end{aligned} \tag{4.7}$$

Taking first order condition and solving for R&D output, we have:

$$x_1 = x_2 = \frac{2(1+\beta+\delta)(2(a-c)-t)}{9\gamma b-4(1+\beta+\delta)^2} \tag{4.8}$$

In order to have positive quantities, we must impose $t < 2(a-c)$ (for $b\gamma > 16/9$). If firms agglomerate in one region (A) and cooperate in R&D (C), its profit will be[24]:

$$\pi^{AC} = \frac{\left(9\gamma b\left(2(a-c)^2+t^2-2(a-c)t\right)-2t^2(1+\beta+\delta)^2\right)}{9b\left(9\gamma b-4\beta^2-4\delta^2-8\delta-4-8\delta\beta-8\beta\right)} \tag{4.9}$$

In addition, we expect to observe that the joint profit is higher if firms discloses its maximum know-how $\{\delta_1=\delta_2=1-\beta\}$. But although it would be optimal to play such strategy, each firm has the belief that it could not hold, because firms' individual profit is higher if she breaches the contract. Actually, we have:

$\pi_1^{NY} > \pi_1^{YY} > \pi_1^{NN} > \pi_1^{YN}$

$\pi_2^{YN} > \pi_2^{YY} > \pi_2^{NN} > \pi_2^{NY}$

and

$\Pi^{YY} > \Pi^{YN} = \Pi^{NY} > \Pi^{NN}$

[24]Second order condition for profit maximization implies $\partial^2\pi_i/\partial x_i^2 < 0$, which is true for $b\gamma > 20/9, \forall\beta\in(0,1), \delta\in(0,1-\beta)$.

where YY denotes that both firms disclose its know-how (*Research Joint-Venture*), YN that firm 1 discloses but firm 2 doesn't, NY that firm 2 discloses but firm 1 doesn't and NN that none of them discloses its know-how (*R&D cartel*).

In order to compel firms to play the optimal strategy, we will impose that firms will incur in a penalty if they do not disclose its know-how. In fact, and as it has been stated by Pérez-Castrillo and Sandonís [159], the inclusion of penalties induce firms to share their know-how when they are simultaneously competitors in the product market. The penalty is then defined as:

$$P = \pi_1^{NY} - \pi_1^{YY} = \pi_2^{YN} - \pi_2^{YY}$$

As firms are symmetric, we just need to focus on one of them. Assume $\delta_1 = 0$ and $\delta_2 = 1 - \beta$. We then have:

$$\begin{aligned} P = \quad & \{-2\gamma[b\gamma\left(2\left(a-c\right)-t\right)^2\left(\beta-1\right)\left(-44b\beta^3\gamma+96\beta^3+68b\beta^2\gamma-96\beta^2+\right. \\ & \left. 27b^2\beta\gamma^2-160\beta-120b\gamma+27b^2\gamma^2+160\right)+64\left(2\left(a-c\right)-t\right)^2\left(\beta-1\right)^4]\} \\ & /\left(32b\beta\gamma-28b\gamma-32\beta+16\beta^2-20b\beta^2\gamma+9b^2\gamma^2+16\right)^2\left(9b\gamma-16\right) \end{aligned}$$

Lemma 4.1 *If firms cluster in the same region, the R&D disclosure effort is contractible and a penalty imposed, then cooperation in R&D is a Nash equilibrium, if* $b\gamma > 16/9$.

Proof. From standard calculation

$$\begin{aligned} \pi^{AC} - \pi^{AN} \quad = \quad & 2\gamma\{\left(2\left(a-c\right)-t\right)^2\left(9\gamma b\left(2\delta+1+4\beta^2+\delta^2-4\beta+2\delta\beta\right)\right. \\ & \left.-4\delta\left(\beta-2\right)^2\left(2\beta+\delta+2\right)\right)\} \\ & /\left(9\gamma b-4\left(1+\beta+\delta\right)^2\right)\left(9\gamma b+4\left(1+\beta\right)\left(\beta-2\right)\right)^2 \end{aligned}$$

If firms make a R&D cartel, then none of them will disclose its know-how ($\delta = 0$) and

$$\pi^{AC} - \pi^{AN} = 2\gamma \frac{(2(a-c)-t)^2 \left(9\gamma b (2\beta - 1)^2\right)}{\left(9\gamma b - 4(1+\beta)^2\right)(9\gamma b + 4(1+\beta)(\beta - 2))^2}$$

where $\pi^{AC} - \pi^{AN} > 0$ for $b\gamma > 16/9$.

If firms make a RJV, then all firms discloses its maximum know-how ($\delta = 1 - \beta$) and

$$\pi^{AC} - \pi^{AN} = 2\gamma \frac{(2(a-c)-t)^2 \left(9\gamma b \left(4 - 6\beta + 3\beta^2\right) - 4(-1+\beta)(\beta-2)^2(\beta+3)\right)}{(9\gamma b - 16)(9\gamma b + 4(1+\beta)(\beta-2))^2}$$

As $\pi^{AC} - \pi^{AN} > 0$ for $b\gamma > 16/9$, then each firms' profit is higher if firms discloses its maximum know-how to the R&D cartel. ■

The relevance of proximity for the emergence of cooperative behaviors is supported by several empirical and theoretical works. Research on the geography of innovation usually supports the hypothesis of the relevance of proximity and knowledge spillovers for cooperation between firms [e.g. Cassiman and Veugelers [36], Belderbos *et al* [24] and Fritsch and Franke [63]].

Baranes and Tropeano [19] developed a model in which two firms choose its location and afterwards engage in R&D cooperation/competition while each firm's researcher effort is not observable. As a result, several equilibria might emerge, depending on the transport cost from one region to another and on each researchers' spillover. They concluded that spatial agglomeration induces firms to voluntarily share knowledge and, at the same time, as it induces tough competition between firms, it spurs knowledge sharing between firms. That is, spatial agglomeration is a commitment on researchers' behavior and thereby a source of confidence between firms, which leads to cooperation and knowledge sharing. Additionally, Long and Soubeyran [130] considered the implications of R&D spillovers that are distance sensitive on the choice of locations by Cournot oligopolists. They also considered the possibility of R&D cooperation within a subset of firms and concluded that agglomeration equilibria might emerge if the spillover function is convex and both demand and cost functions were linear.

Example 4.1 Assume firms are *agglomerated* in one region and $b = 1, \gamma = 5, a - c = 50$. We then have that, for every spillover rate and for every transport costs, firms' individual profits are higher if firms cooperate in R&D when comparing with R&D competition, provided a penalty is applied if firms do not exert the contractible disclosure effort (figure 4.1):

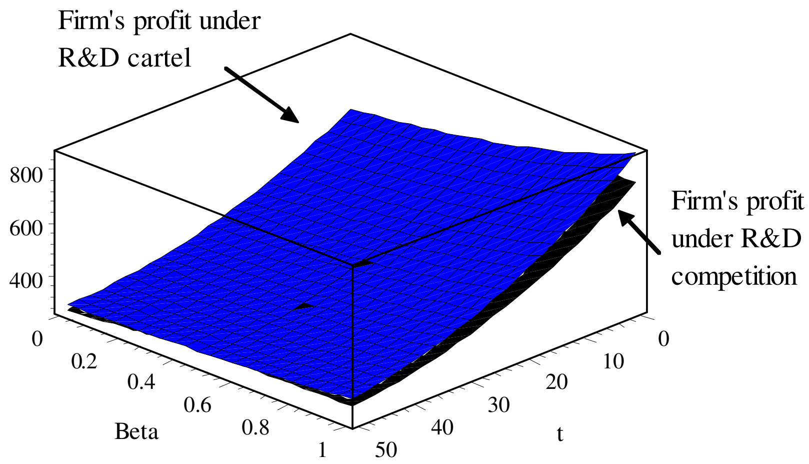

Figure 4.1. Firm's profit under spatial agglomeration: R&D competition and R&D cartel

Additionally, each firm's profit is higher if a higher disclosure effort is supplied. In effect, we have that firm's individual profit is higher under a RJV ($\delta = 1 - \beta$) than under a R&D cartel ($\delta = 0$) (figure 4.2):

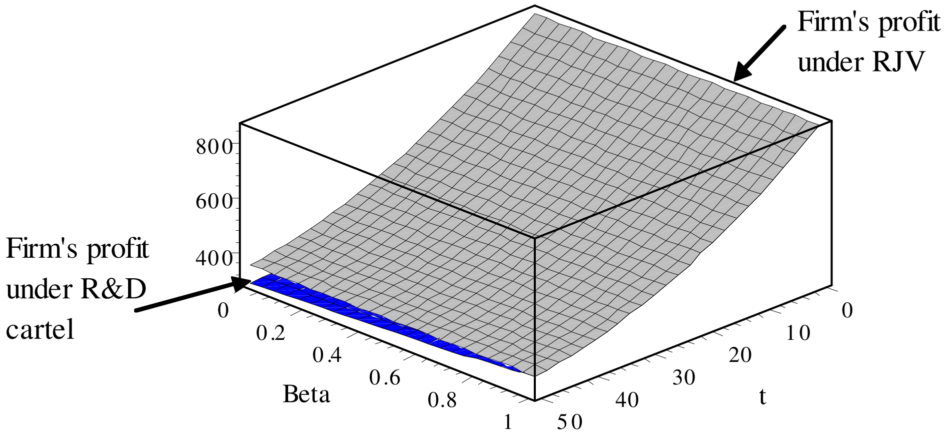

Figure 4.2. Firm's profit under spatial agglomeration: RJV and R&D cartel

4.6 Dispersion

Assume firms choose to locate in separated regions (A, B). As regions are symmetric, we will assume, without loss of generality, that firm 1 chooses to locate in region A and firm 2 chooses to locate in region B. We then have:

$$\begin{aligned}
\pi_1 &= (a - bQ_A - c + x_1 + \delta_2 x_2)\, q_{1A} \\
&\quad + (a - bQ_B - c - t + x_1 + \delta_2 x_2)\, q_{1B} - \gamma\,(x_1)^2/2 \\
\pi_2 &= (a - bQ_A - c - t + x_2 + \delta_1 x_1)\, q_{2A} \\
&\quad + (a - bQ_B - c + x_2 + \delta_1 x_1)\, q_{2B} - \gamma\,(x_2)^2/2
\end{aligned} \tag{4.10}$$

4.6.1 Firms' behavior in the product market

Taking first order conditions from (4.10) and solving for the equilibrium quantities:

$$
\begin{aligned}
q_{1A} &= \frac{1}{3b}\left(a-c+t+2x_1-x_2-\delta_1 x_1+2\delta_2 x_2\right) \\
q_{1B} &= \frac{1}{3b}\left(a-c-2t+2x_1-x_2-\delta_1 x_1+2\delta_2 x_2\right) \\
q_{2A} &= \frac{1}{3b}\left(a-c-2t-x_1+2x_2+2\delta_1 x_1-\delta_2 x_2\right) \\
q_{2B} &= \frac{1}{3b}\left(a-c+t-x_1+2x_2+2\delta_1 x_1-\delta_2 x_2\right)
\end{aligned} \tag{4.11}
$$

So, if firms choose to locate in different regions, then they will face the following profit function[25]:

$$
\begin{aligned}
\pi_1 &= [\left(a-c+t+2x_1-x_2-\delta_1 x_1+2\delta_2 x_2\right)^2 \\
&\quad +\left(a-c-2t+2x_1-x_2-\delta_1 x_1+2\delta_2 x_2\right)^2]/9b-\gamma\left(x_1\right)^2/2 \\
\pi_2 &= [\left(a-c-2t-x_1+2x_2+2\delta_1 x_1-\delta_2 x_2\right)^2 \\
&\quad +\left(a-c+t-x_1+2x_2+2\delta_1 x_1-\delta_2 x_2\right)^2]/9b-\gamma\left(x_2\right)^2/2
\end{aligned} \tag{4.12}
$$

4.6.2 R&D decision

4.6.2.1 R&D competition

If firms run R&D independently, then they will maximize individual profit functions and $\delta_1 = \delta_2 = 0$:

[25] Second order condition for profit maximization implies $\partial^2 \pi_i / \partial x_i^2 < 0$, which is true for $b\gamma > 16/9, \forall \beta \in (0,1)$.

$$\begin{aligned}\pi_1 &= [(a-c+t+2x_1-x_2)^2+(a-c-2t+2x_1-x_2)^2]/9b \\ &-\gamma(x_1)^2/2 \\ \pi_2 &= [(a-c-2t-x_1+2x_2)^2+(a-c+t-x_1+2x_2)^2]/9b \\ &-\gamma(x_2)^2/2\end{aligned} \tag{4.13}$$

Taking first order from (4.13) and solving for R&D output gives us

$$x_1 = x_2 = \frac{8(a-c)-4t}{9b\gamma-8} \tag{4.14}$$

In order to impose positive quantities, we must have $t < 2(a-c)$ (for $b\gamma > 8/9$).

If firms disperse (D) and compete in R&D (N), then we have:

$$\pi^{DN} = \frac{2b\gamma(a-c)((a-c)-t)(9b\gamma-16)+t^2(45b^2\gamma^2-80b\gamma+32)}{b(9b\gamma-8)^2} \tag{4.15}$$

4.6.2.2 R&D cooperation

Although firms are dispersed, they may engage in R&D cooperation. However, they will face uncertainty, as they do not know if their rival will disclosure its know-how. For our purposes, we will assume two disclosure efforts: either firms do not disclose its know-how to its partner $\{\delta_1 = 0, \delta_2 = 0\}$ or firms totally discloses its know-how $\{\delta_1 = 1, \delta_2 = 1\}$. Additionally, we will assume that firms are uncertain about each other's disclosure effort, but have information about the probability, p, that each firm discloses its know-how. For simplicity, we will assume that both firms are symmetric and p is identical to both firms.

The R&D decision is then reduced to:

$$\underset{x_1,x_2}{Max}\ E(\Pi) = E(\pi_1+\pi_2) \tag{4.16}$$

We then have:

$$
\begin{aligned}
E(\Pi) &= E(\pi_1) + E(\pi_2) \qquad (4.17)\\
&= \frac{2}{9b}[p^2(2a^2 - 4ac - 2at + 4ax_1 + 4ax_2 + 2c^2 + 2ct - 4cx_1 - 4cx_2 + 5t^2 \\
&\quad -2tx_1 - 2tx_2 + 2x_1^2 + 4x_1x_2 + 2x_2^2) + p(1-p)(2a^2 - 4ac - 2at + 4ax_1 \\
&\quad +2ax_2 + 2c^2 + 2ct - 4cx_1 - 2cx_2 + 5t^2 - 2tx_1 - tx_2 + 2x_1^2 + 2x_1x_2 + 5x_2^2) \\
&\quad +(1-p)p(2a^2 - 4ac - 2at + 2ax_1 + 4ax_2 + 2c^2 + 2ct - 2cx_1 - 4cx_2 \\
&\quad +5t^2 - tx_1 - 2tx_2 + 5x_1^2 + 2x_1x_2 + 2x_2^2) + (1-p)^2(2a^2 - 4ac - 2at \\
&\quad +2ax_1 + 2ax_2 + 2c^2 + 2ct - 2cx_1 - 2cx_2 + 5t^2 - tx_1 - tx_2 + 5x_1^2 \\
&\quad -8x_1x_2 + 5x_2^2)] - 0.5\gamma(x_1)^2 - 0.5\gamma(x_2)^2
\end{aligned}
$$

Taking first-order conditions and solving for R&D output:

$$
x_1 = x_2 = \frac{4(a-c) - 2t - 2pt + 4p(a-c)}{9b\gamma - 28p + 16p^2 - 4} \qquad (4.18)
$$

In order to have positive quantities, we must impose $t < 2(a-c)$ (for $b\gamma > 16/9$) . If firms disperse (D) and cooperate in R&D (C), we then have[26]:

$$
\begin{aligned}
E\left(\pi^{DC}\right) &= [45\gamma bt^2 - 40p(a-c)^2 - 40p^2(a-c)t + 40p^2(a-c)^2 \qquad (4.19)\\
&\quad +82p^2t^2 + 40p(a-c)t - 136pt^2 - 18t^2 + 18(a-c)^2\gamma b \\
&\quad -18(a-c)t\gamma b]/9b\left(9\gamma b - 28p + 16p^2 - 4\right)
\end{aligned}
$$

Lemma 4.2 *If firms locate in different regions, the R&D disclosure effort is contractible but uncertain and a penalty imposed, then cooperation in R&D is a Nash equilibrium, if $b\gamma > 4/3$.*

Proof. From standard calculation

[26]Second order condition for profit maximization implies $\partial^2\pi_i/\partial x_i^2 < 0$, which is true for $b\gamma > 8/9, \forall p \in (0,1), \delta \in (0,1)$.

$$E(\pi^{DC})-\pi^{DN}=\frac{2}{9}\left(2\left(a-c\right)-t\right)^{2}\frac{9b\gamma\left(9\gamma b+p\left(9\gamma b-16\right)\left(p+2\right)\right)-320p\left(p-1\right)}{b\left(9\gamma b-4-28p+16p^{2}\right)\left(9\gamma b-8\right)^{2}}$$

where $E(\pi^{DC})-\pi^{DN}$>0, for $p\in(0,1)$ and $b\gamma>4/3$. ■

Proposition 4.1 *If the R&D disclosure effort is contractible and a penalty imposed, then cooperation in R&D is a Nash equilibrium of the R&D game.*

Proof. As results from lemma (1) and (2). ■

Example 4.2 Assume firms are *dispersed* in two regions and $b=1,\gamma=5,a-c=50$.We then have that firms' individual profits are higher if firms cooperate in R&D when comparing with R&D competition, provided a penalty is applied if firms do not exert the contractible disclosure effort. Additionally, each firm's profit is higher if the probability that both firms discloses its maximum know-how is higher (figure 4.3):

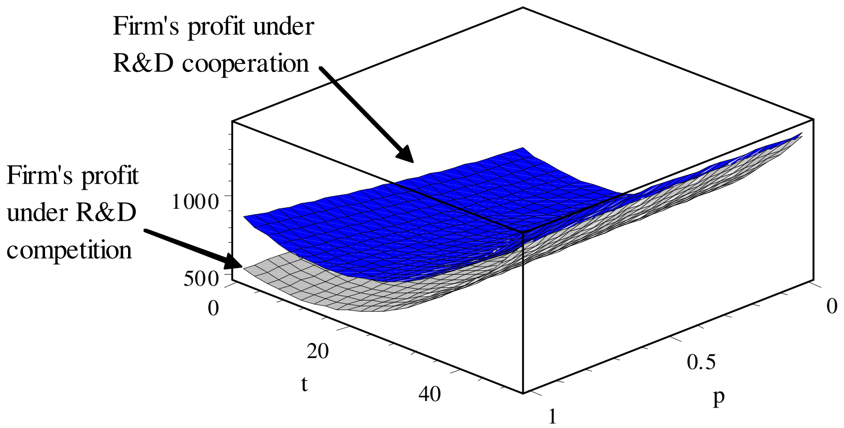

Figure 4.3. Firm's profit under spatial dispersion: R&D competition and R&D cooperation

Proposition 4.2 *If the R&D disclosure effort is contractible and a penalty imposed, then, for a sufficiently high transport cost, the subgame perfect equilibrium for the location - R&D game is {dispersion, cooperation}, if* $b\gamma>16/9$.

Proof. From standard calculations, we have:

$$\begin{aligned}\pi^{AC}-E\left(\pi^{DC}\right) &= -2[-4t^{2}\left(37p^{2}-61p-8\right)-80\left(a-c\right)p\left(p-1\right)\left(-t+\left(a-c\right)\right) \\ &-9b\gamma(-18\gamma bt^{2}+4\left(a-c\right)\left(\beta+\delta-p\right)\left(\beta+2+\delta+p\right)\left(-t+\left(a-c\right)\right) \\ &+t^{2}\left(16+9\delta^{2}+9\beta^{2}+18\delta+18\beta+18\delta\beta-33p^{2}+54p\right)) \\ &-4t^{2}\left(37p^{2}-61p-8\right)\left(\beta+2+\delta\right)\left(\beta+\delta\right) \\ &-80\left(a-c\right)p\left(\beta+2+\delta\right)\left(\beta+\delta\right)\left(p-1\right)\left(-t+\left(a-c\right)\right)] \\ &/9b\left(9\gamma b-4\beta^{2}-4\delta^{2}-8\delta-4-8\delta\beta-8\beta\right)\left(9\gamma b-28p+16p^{2}-4\right)\end{aligned}$$

If firms disclose its maximum know-how to the RJV ($\delta=1-\beta$), then $\pi^{AC}-E\left(\pi^{DC}\right)<0$ if $b\gamma>16/9$ and for a sufficiently high t .

If firms do not disclose its know-how to the R/&D cartel ($\delta=0$), then $\pi^{AC}-E\left(\pi^{DC}\right)<0$ if $b\gamma>16/9$ and for sufficiently high t. ■

Corollary 4.1 *If the R&D disclosure effort is contractible and a penalty imposed, then, for a sufficiently low transport cost and high uncertainty on the disclosure effort, the subgame perfect equilibrium for the location - R&D game is {agglomeration, cooperation}, if* $b\gamma>16/9$.

Example 4.3 Assume $b=1,\gamma=5,a-c=50$. We then have that, for a sufficiently high transport costs, firms' individual profits under R&D cooperation are higher if firms disperse than when they agglomerate: $E\left(\pi^{DC}\right)>\pi^{AC}$ for $t>20$ (figure 4.4):

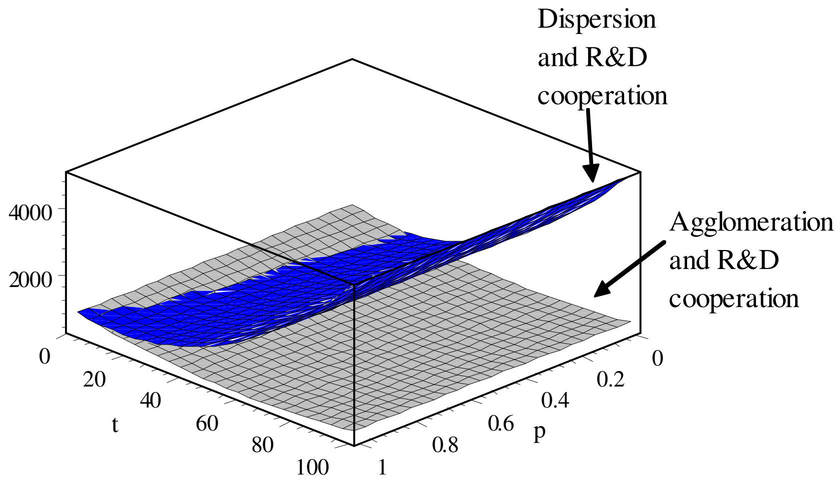

Figure 4.4. Firm's profit under R&D cooperation: Agglomeration and dispersion

It is then possible to conclude that, for high transport costs, firms would prefer to disperse between regions than to agglomerate. This conclusion is strongly support by the *New Economic Geography* models (e.g. Fujita, Krugman and Venables [64]), which predict that there is a monotonic decreasing relationship between the degree of agglomeration and the level of transport costs. Additionally, we may observe that, for low transport costs, cooperating firms prefer to firms agglomerate if the probability of disclosing its maximum know-how is low. This conclusion is rather intuitive and results from the reduction of uncertainty in R&D cooperation when firms are agglomerated. In effect, if the probability that firms discloses its maximum know-how is high, then cooperating firms will disperse and thus lessen the weight of transport costs. However, if this probability is low, then firms will agglomerate, as uncertainty is reduced when they co-locate.

4.7 Concluding Remarks

The purpose of this research was to evaluate if spatial competition between firms influences its decision about location and R&D cooperation, when they benefit from knowledge spillovers. Our model intends to improve previous research by assuming that competing firms may engage in R&D cooperation and choose the disclosure effort, which is uncertain if firms were dispersed. We were able to demonstrate that, under spatial competition, firms may take advantage of R&D cooperation to replicate the benefits of agglomeration. In fact, we were able to conclude that, provided a penalty is applied for any deviation behavior, firms will cooperate in R&D, either if they were agglomerated or dispersed. Additionally, if firms cooperate in R&D and choose the disclosure effort between them, then the R&D spillovers are internalized, which lead firms to disperse for a sufficiently high transport cost. However, and as firms face uncertainty with respect to the disclosure effort if they were dispersed, we might observe agglomeration if transport costs are sufficiently low.

Our results are therefore sufficiently intuitive and find confirmation in empirical research and other economic models. In effect, several scholars claim that R&D cooperation networks might involve uncertainty and/or information asymmetry (e.g. Choi [39] [40], Combs [44], Hauenschild [86], Morasch [142], Pastor and Sandonís [158]). Particularly, the amount of know-how each firm discloses to the R&D cartel might be uncertain and/or unobservable (Pérez-Castrillo and Sandonís [159], Rosenkranz [169]). Additionally, proximity between firms seems to reduce uncertainty when competing firms are involved in cooperation (Baranes and Tropeano [19]). It is, then, most likely that firms agglomeration may reduce uncertainty and therefore uphold R&D cooperation if transport costs are not too high. If transport costs are sufficiently high, we might expect to observe dispersion, as it was realized by Krugman [124] and other new economic geographers. In this case, firms may overcome the absence of knowledge spillovers by cooperating in R&D if uncertainty with respect to disclosure effort is not too high.

Research on spatial competition and R&D cooperation is far from being concluded. We expect to improve this research in several directions. One possible line of research is to extended previous framework to a n-firms model, and evaluate agglomeration or dispersion equilibria under cooperation in R&D among a subset of firms. Another research topic is to assume that firms may have private information about the degree of information sharing. In this case, information asymmetry exists, which could be reduced if firms locate in the same region. An incentive contract should then be developed, while it turns to be a double moral hazard contract if firms were dispersed.

Chapter 5

The Determinants of Firms' Location Choice

5.1 Introduction

Understanding the determinants of business location choice is the subject of a large body of literature, comprising both theoretical and empirical research. In fact, alongside with renowned contributes for optimal location theory that claim the importance of cost factors, demand variables and agglomeration economies for the decision about location, numerous empirical studies have examined the relative significance of various factors in the business site selection process. However, literature is scarce concerning both technological and entrepreneurial features that might influence plant location.

In this chapter, we intend to evaluate the importance of both geographical, sectorial and technological determinants for firms' decision about location. For that purpose, we make use of micro-level data for the Portuguese manufacturing sector and focus on the location choices made by new starting plants during 1992-2000 within 275 municipalities. We considered the entire manufacturing sector, and also samples according to both the number of plants and firms' technological intensity. The set of explanatory variables includes variables that are traditionally stressed by urban and regional theory, such as production costs (land, labor and capital costs), demand indicators and agglomeration economies (urbanization and localization economies), as well as technological variables, such as the R&D expenditures.

The model is based on the random utility maximization framework and proceeds through a Poisson model and a Negative Binomial regression. From our results, we were able to conclude that for the total manufacturing sector, the main determinants for firms' location decision were the agglomeration economies and both labor and land costs. However, when we consider the multi-plant versus the single-plant location choices, we were able to conclude that new multi-plant firms are particularly sensitive to urbanization economies, land costs and local market, while new single-plant firms are more responsive to labor costs and agglomeration economies. Additionally, when considering the high-tech sample, we conclude that the cost determinants for location lose importance, whilst the urbanization economies and the R&D expenditures gain relevance.

The remainder of the chapter is organized as follows. Next section is devoted to an overview of main contributes for location theory. Then, we focus on econometric studies on industrial location choice and present our methodology that relies on the Random Utility Maximization framework. Afterwards, we proceed through a detailed description of data and variables we considered in our study and construct the main hypotheses. Finally, we present the empirical results and concluding remarks.

5.2 Location Theory: A Brief Overview

According to Greenhut [75][27], location theory may be defined as a set of propositions that aims at explaining the spatial organization of economic activities. Although it is possible to find rudiments of the location theory in the writings of many classical economists

[27] In this section, we build on Figueiredo and Guimarães [58] for this overview.

(Smith, Ricardo, Mill), the interest in plant location theory may be attributed to three Germans: Launhardt, Von Thünen and Weber, who proposed that the optimal location of the firm corresponds to the least cost site (*Least-cost theory*). Another approach, launched by Hotelling, focus on the demand side and postulates that the optimal location results from the determination of the optimal market area in a context of spatial competition (*Spatial interaction theory*). Finally, Lösch suggested that the optimal location depends both on the costs and revenues that derives from each location (*Profit maximization theory*).

- **The least cost theory**

The cost minimizing theory emphasizes the search for the least cost site by abstracting from demand and by assuming competitive pricing, different costs among locations and a given buying center (Greenhut [73]). Early contributes are due to Von Thünen [193], who was primarily concerned with agricultural locations (nevertheless, its theory is applicable to manufacturing locations). In the Von Thünen's model, cost differences across sites are due to the land rent and the transportation expense, while the cost of production is the same everywhere. Therefore, the land rent and the cost of transporting goods are the effective co-determinants of location. Focusing on industrial location, Weber [195] highlighted the relationships between the input-output structure of the firm's production function and the influences of input and output transportation costs on the firm's optimum location[28]. In Weber's framework, the determinants of each firm's location are the transportation costs, labor costs and the agglomerating (deglomerating) forces. Within a fixed technical coefficients framework, high transport costs tend to imply proximity, whereas the prices of inputs and output goods play no role on the determination of the optimum location of the firm.

- **The spatial interaction theory**

The increasing awareness of the limitations of the least-cost analysis led to the development of the *spatial interaction theory* that focus on the demand side. Under the influence

[28]While similar to Launhardt's theory, Weber's theory of location is the opposite of von Thünen's. In the earlier writer's scheme, the location is given and the type of production is to be determined; in Weber's theory, the branch of industry is given and the place of location is sought (Greenhut [74]).

of Fetter [57], Hotelling [98], Lerner and Singer [128] and Chamberlin [37], among others, focus was made on the spatial competition between firms. Departing from oligopoly models, they assumed that buyers were scattered over an area and production costs were equal at all locations while delivered price varies with location. As a result, the optimal location results from the determination of the optimal market area in a context of spatial competition between firms. Among others factors, the optimal location of the firm is influenced by the elasticity of the industrial demand curve, the height of the freight cost and the characteristics of the marginal production costs. Additionally, the actual location is also determined by entrepreneurial expectations about the rival firms' location policies and the type of interdependence between firms. By focusing on the demand side and abstracting from cost analysis, the spatial interaction only yields a one-side theory.

- **The profit maximization theory**

Lösch [131] reached the core of the location problem when he noted that to seek the lowest cost location is as wrong as looking for the largest market area, providing the fundaments for the *profit maximization theory*. He developed the first systematic economic analysis of the location decision which postulates that the optimal location is the one that assures maximum profit for the entrepreneur. Lösch assumed that consumers were scattered along a homogeneous landscape and support transport costs to achieve the good, which allow him to derive a demand function over space. He then constructed a zero-profit market-area for each seller and obtained a collection of hexagons that describe each seller's market-area. He concluded that the extent of the concentration of production depends both on the increasing returns to scale and on the transportation costs.

According to Greenhut [74], although Lösch was the first to propose that the location of a manufacturing plant depends both on production costs and market area it assigns to each location, he failed to combine an analysis of intra-industry cost and demand differentials in one model. In fact, Lösch's theory fails to include costs differentials (others than those attributable to advantages of agglomeration and transportation) or to regard the principles of interdependence (which cause extraordinary concentrations of homogeneous business units).

In spite of adopting different approaches to the location choice problem, all these models are based on neoclassical deductive micro-economic reasoning. In fact, they all represent partial equilibrium, static and normative models, defining the 'optimal' behavior of the firm under the assumptions of rationality and perfect information of the entrepreneur.

- **Other approaches**

Recently, other approaches to the location theory have been developed that contrast with the assumption of the entrepreneur as a rational decision maker. According to Mariotti [135], the *behavioral location theory* interprets firms as agents that have limited information, are bounded rational and settle for sub-optimal outcomes rather than maximum profits. It explores 'internal' factors (e.g., age and size) that are important in the decision-making process of the firm, and that lead to a particular location.

Another approach is the *institutional location theory*, which starts from the assumption that economic activity is socially and institutionally situated: it is shaped by society's cultural institutions and value systems rather than by firm behavior. In the institutional theory, 'external' or 'institutional' factors (e.g., spatial adjustments such as expansion, merger, acquisition and take-over, but also trust, reciprocity, cooperation and convention) play a key role at all levels in the economy, from the structure and functions of the firm, through the operation of markets, to the form of state intervention.

Finally, the *evolutionary approach* states the relevance of routine behavior founded on the mechanism of selection and path dependence for location's decisions.

In spite of their relevance for the location choice analysis, particularly when focusing on particular location contexts (e.g. relocation), these approaches are still in an early stage of development. Additionally, most empirical studies focus on the traditional approach and so, in order to made possible the comparability of our results, we will adopt this line of research.

5.3 The Determinants of Firms' Location: Related Literature

According to Figueiredo and Guimarães [58], empirical research on the determinants of location choice may proceed either by using the survey method or by means of econometric modeling. In the first case, firms are required to identify the determinants of its actual location (*stated preferences*). The survey method allows us to obtain very rich data and to understand the ranking among alternatives, being extremely relevant when historical information is unavailable. However, the stated preferences about location may differ from the real ones, while the results are highly responsive to sample characteristics. The second approach appeals to econometric models where the actual location of the firm is put against a set of explanatory variables. In this case, the researcher uses historical data that depict actual choices (*revealed preferences*) and intend to identify the factors influencing choices. The robustness of the econometric approach and the recent advances in econometric techniques led us to adopt this line of research.

There are two strands of the literature that use econometric modelling to evaluate firms' location determinants. One tradition appeals to discrete choice modelling and derives from the Random Utility Maximization framework (e.g. Carlton [34] and Bartik [22]). Usually, the depend variable is a discrete or count variable, which is put against a set of explanatory variables that includes cost, demand and agglomeration determinants for firms' location choice. Another approach focus on firms' birth rate, either by adopting an evolutionary approach (new firms/total firms) or a labor market approach (new firms/labor force). In both cases, a linear regression model is usually adopted (e.g. Guesnier [78], Audretsch and Fritsch [17], Keeble and Walker [122], Garofoli [68], Armington and Acs [12], Sutaria and Hiks [181]). Typically, the set of explanatory variables includes the rate of change of variables that capture the importance of agglomeration economies, government policy, labor and market conditions for location choice. However, the compatibility of this approach with the profit maximization framework has not been clarified, and, for this reason, we will not adopt this line of research.

Early discrete choice models on the determinants of location decision focused on the location choices made by new firms within a small set of alternatives. Carlton [34] was the first to apply discrete choice models to the location problem. He estimates the decision where to locate in three narrowly defined industries: plastic products, communication equipment and electronic components in the United States. Using simple logit models, Carlton concluded for the importance of agglomeration economies and energy costs for the location choice. Subsequent research on spatial probability choice has relied on Carlton's approach[29] .

Likewise, Bartik [22] uses a conditional logit model to estimate the location decision of new manufacturing firms in United States. The empirical results suggests that the rates of unionization and agglomeration economies has a strong effect on new business activity. Similarly, Schmenner, Huber and Cook [173] look at the location choice of new manufacturing firms in US but uses a two-stages logit model. They concluded for the relevance of energy costs. Hansen [85] focus on the location of manufacturing firms in São Paulo (Brazil) by means of a nested logit model. He made relevance of both localization and urbanization economies for the location choice.

Following these early location studies, and as a consequence of the popularity of the discrete choice analysis, several other studies were developed. Some researchers focus on the location of new foreign firms and look for the importance of economic characteristics of the host region, such as market variables, labor costs and government policy for location choice. This was the case of Coughlin, Terza and Arrondee [46], Friedman, Gerlowski and Silberman [61], Woodward [197], Shaver [175], Wei, Liu, Parker and Vaidya [196], Wu [199] [200], Head, Ries and Svenson [88] and Guimarães, Figueiredo and Woodward [79], among others. Usually, these studies support the relevance of agglomeration economies (particularly, urbanization economies), market accessibility and the existence of institutional support for foreigner investments for the location choice of foreigner firms, while the importance of labour and land costs seems to be inconclusive.

Recently, some researchers claim that the sectorial and geographical variables affect differently location choice according to firms' size (e.g. Araúzo-Carod and Manjón-Antolín [11]), firms' industrial activity (e.g. Araúzo-Carod [10]) or technological intensity (e.g.

[29]Without any intention to be exhaustive, we present, in appendix, the main results of several empirical studies that employ discrete choice models to evaluate firms' location choice.

Barrios, Görg and Strobl [20]), new and relocated firms (e.g. Holl [95]) and entrepreneur's preference for the home base (e.g. Figueiredo, Guimarães and Woodward [59]). Although some general tendencies still be evidenced (e.g. the relevance of agglomeration economies for location choice), some location determinants seem to have a quite different influence on location choice according to firms' characteristics.

The methodological approach to location choice has also evolved in recent years, and for that reason, we next present a brief description of the main methodologies that were implemented in previous studies on location choice.

5.4 Methodology

Research on firms' decision about location usually appeals to discrete-choice models that rely on the Random Utility Maximization framework of McFadden [141]. This methodology was first implemented on location choice by Carlton [34] and most subsequent research on spatial probability choice has relied on his approach [e.g., Bartik [22], Hansen [85], Schmenner, Huber and Cook [173], Coughlin, Terza and Arrondee [46], Friedman, Gerlowski and Silberman [61] and Woodward [197], among many others).

In the *conditional logit framework*, decision probabilities are modelled in a partial equilibrium setting where firms maximize profits subject to uncertainty that derives from unobservable characteristics. As in Guimarães, Figueiredo and Woodward [80], we will consider an economy with K industrial sectors ($k = 1, ..., K$) and assume that there are N investors ($i = 1, ..., N$) who independently select a location j from a set of J potential locations ($j = 1, ..., J$). The potential profit that a firm i assigns to each location j and each industrial sector k is:

$$\pi_{ijk} = \boldsymbol{\alpha}' x_j + \boldsymbol{\phi}' y_k + \boldsymbol{\beta}' z_{jk} + \varepsilon_{ijk} \tag{5.1}$$

where $\boldsymbol{\alpha}$, $\boldsymbol{\phi}$ and $\boldsymbol{\beta}$ are vectors of unknown parameters, x_j is a vector of location specific variables, y_k is a vector of sector specific variables and z_{jk} is a vector of variables that change simultaneously with the sector and the location. ε_{ijk} is an identically and independently random term with a Gumbel (or type I extreme value) distribution.

For every spatial option, the investor will compare expected profits and choose alternative r if:

$$\pi_{irk} > \pi_{ijk}, \forall j \neq r \tag{5.2}$$

Due to the stochastic nature of the profit function, the probability that an investor i of the industrial sector k chooses the location j is:

$$P_{j|k} = Prob(\pi_{irk} > \pi_{ijk}) \tag{5.3}$$

Or, similarly;

$$P_{j|k} = \frac{\exp\left(\boldsymbol{\alpha}' x_j + \boldsymbol{\beta}' z_{jk}\right)}{\sum_{j=1}^{J} \exp\left(\boldsymbol{\alpha}' x_j + \boldsymbol{\beta}' z_{jk}\right)} \tag{5.4}$$

which expresses the conditional logit model formulation.

According to Guimarães, Figueiredo and Woodward [81], the lack of available data sets led some scholars to model location decision among highly aggregated regions, such as the US States (e.g. Bartik [22], Coughlin, Terza and Arrondee [46], Friedman, Gerlowski and Silberman [61] and Head, Ries and Swenson [88]) or the Indian states (Mani, Pargal and Huq [134]). However, large geographical units encompass a lot of heterogeneity within them. At the same time, this procedure ignores local characteristics that are usually relevant for the location choice. Alternatively, some authors modeled the location choice within a restricted area (e.g. Hansen [85] and Wu [200]). Instead, other researchers choose to use detailed geographical information, and, as consequence, larger data sets but followed McFadden's suggestion to work with a small sample of location sites randomly chosen from the full data set (e.g. Woodward [197] and Guimarães, Figueiredo and Woodward [79]). By this procedure, consistency is guaranteed, but estimators may be inefficient, as this method still disregards relevant local information.

However, the conditional logit model assumes that the odds of choosing an alternative are a function of its attributes but are independent of other alternatives, which is known as the *Independence of Irrelevant Alternatives* assumption (IIA) (Greene [71]). This proposition may be implausible in location choice, as adjacent locations may have similar characteristics, which make them interdependent. Moreover, if the IIA assumption is violated, then it leads to biased coefficient estimates.

In order to accommodate the IIA assumption in the location choice, some researchers recurred to the *nested logit model*, which presumes that alternatives are grouped in subgroups so that variance differs across groups while maintaining the IIA assumption within the groups (Greene [71]). Let us suppose that the J locations can be grouped into R groups. Thus, the probability of an investor i chooses to locate in region j is $P_{jkr} = P_{jk|r} * P_r$, where

$$P_{jk|r} = \frac{\exp\left(\boldsymbol{\alpha}' x_{j|r} + \boldsymbol{\beta}' z_{jk|r}\right)}{\sum_{j=1}^{J_1} \exp\left(\boldsymbol{\alpha}' x_{j|r} + \boldsymbol{\beta}' z_{jk|r}\right)} \tag{5.5}$$

$$P_r = \frac{\exp\left(\boldsymbol{\theta}' w_r + \sigma_r I_r\right)}{\sum_{r=1}^{R} \exp\left(\boldsymbol{\theta}' w_r + \sigma_r I_r\right)} \tag{5.6}$$

where w_r is the vector of characteristics specific to each group r and I_r represents the average profit that an investor expects to obtain from the alternatives within each group r (note that $I_r = 1$ if we intend to produce the original conditional logit model). Estimation usually proceeds by means of a two-step limited information maximum likelihood procedure (e.g. Hansen [85], Barrios, Görg and Strobl [20], Head and Mayer [87] and Pusterla and Resmini [166]). However, to specify the nested logit model, it is necessary to define a partition of the spatial choice set in upper and lower levels, which implies that the results might depend on the definition of those levels. In addition, this procedure is only valid if the IIA assumption holds within the subgroup of the choice set.

A recent strand of the literature, launched by Guimarães, Figueiredo and Woodward [80], has modelled the location choice by means of a *Poisson model* (e.g. Wu [199], Guimarães, Figueiredo and Woodward [81] and Araúzo-Carod [10]). Under this formulation, the number of new firms that choose a specific location is a count variable and relates to a vector of local characteristics[30]. So, the probability that the number of firms that chooses location j is n_j is given by:

$$P(n_j) = \frac{e^{-\lambda_j}.\lambda_j^{n_j}}{n_j!} \tag{5.7}$$

Additionally, the coefficients of the conditional logit model can be equivalently estimated by using a Poisson regression through maximizing the following log-likelihood, where n_{jk} denotes the number of investments carried out in sector k and region j:

$$\log\ L = \sum_{k=1}^{K}\sum_{j=1}^{J} n_{kj}\ \log P_{j|k} \tag{5.8}$$

which is equivalent to that of the Poisson model which takes n_{jk} as a dependent variable and includes as explanatory variables x_j and z_{jk} vectors plus a set of dummy variables for each sector. That is, we will obtain the same results if we admit that n_{jk} follows a Poisson distribution with

$$\lambda_j = \exp\left(\boldsymbol{\omega}_k + \boldsymbol{\alpha}' x_j + \boldsymbol{\beta}' z_{jk}\right) \tag{5.9}$$

where $\boldsymbol{\omega}_k$ is a dummy variable that takes the value 1 for sector k (0 otherwise).

Moreover, and according to Araúzo-Carod [10], the number of alternatives in a conditional logit model equals the number of observations in a Poisson model, which implies

[30] Other authors used the logistic model to estimate count variables, as it allows to transform count-data into a binary variable (e.g. Shaver [175] and Wu [200]).

that increasing the number of alternative locations is not a major problem. The Poisson model also allows to overcome any modelisation problems due to the existence of nill observations (unlike conditional logit models).

It should be said that the Poisson regression model assumes that the conditional mean λ_j equals the conditional variance, that is, $E(n_{jk}) = Var(n_{jk}) = \lambda_j$. But, frequently, the variance is larger than the one assumed by the Poisson model, a result called *overdispersion*. Overdispersion is a form of heteroscedasticity which yields downward biased estimates of the standard errors, although consistent estimates of the parameters. In the case of location choice, we expect to observe overdispersion due to the concentration of firms in some locals. To overcome this problem, the Poisson model can be extended to a negative binomial model([31])([32]).

The *negative binomial distribution* is an extension of the Poisson model that allows the variance of the process to differ from its mean. Thus, the probability that the number of firms that choose location j is n_j is given by mixing the Poisson model with a gamma distribution:

$$P(n_j) = \frac{\Gamma(\theta + n_j)}{\Gamma(1 + n_j)\Gamma(\theta)} \left(\frac{\lambda_j}{\lambda_j + \theta}\right)^{n_j} \left(\frac{\theta}{\lambda_j + \theta}\right)^{\theta} \tag{5.10}$$

where Γ is the gamma distribution, $E(n_{jk}) = \lambda_j$ and $Var(n_{jk}) = \lambda_j\,(1 + \lambda_j/\theta)$. The negative binomial model can be estimated by maximum likelihood (e.g. Wu [199], Coughlin and Segev [45] and Holl [95]).

In this research, we intend to evaluate the importance of local and sectorial determinants for firms' location choice within a large set of spatial alternatives. For that purpose, we will run on the steps of the Random Utility Maximization framework and take advantage of the equivalence between the conditional logit model and the Poisson regression, which

[31] Other solutions introduce a dispersion parameter θ so that $Var(n_{jk}) = \theta E(n_{jk})$ or estimate the dispersion parameter as a ratio of the deviance or the Pearson Chi-Square to its degrees of freedom. However, these procedures only gives a correction term for testing the parameter estimates under the Poisson model.

[32] Additionally, Woodward, Figueiredo and Guimarães [198] proposed the Dirichlet-Multinomial model, which is an extension of the conditional logit model that allows for overdispersion.

allows us to overcome a potential IIA violation. Additionally, whenever overdispersion is observed then the negative binomial model will be employed.

5.5 Data and Hypotheses

This research aims at evaluate the importance of local and sectorial characteristics for firms' location choice. For that purpose, we make use of micro-level data for the Portuguese manufacturing sector and focus on the location choices made by new starting plants during 1992-2000 within 275 municipalities. The set of explanatory variables includes variables that are traditionally stressed by location theory, such as production costs, demand indicators and agglomeration economies, as well as technological variables.

In this section, we intend to explain the construction of our data-set and, having under consideration both location theory and empirical studies on location choice, formulate main hypotheses. First, we will focus on the explained variable - new plant births - and afterwards, we will concentrate on the set of explanatory variables and formulate main hypotheses.

5.5.1 Dependent variable

Plant births from 1992 and 2000 were calculated from *Quadros do Pessoal* (DEEP - MTE [50]). This statistical database is built on a compulsory survey collected annually by the Portuguese Ministry of Employment for all business firms operating in Portugal[33]. The inquiry collects information at the firm, plant and worker level since 1982, including data on firms' location, economic activity, capital structure, number of plants, employees and giving a particular emphasis to the workforce characteristics.

By using a unique identifying number addicted to each firm and its establishments and employees, we were able to merge data about firms, plants and labor force. However,

[33] *Quadros do Pessoal* does not cover public administration or domestic service and excludes firms without wage-paid employees or start-ups with a very short life up to 12 months.

this identifying number was modified in 1991, leading us to limit our study to the period 1992 to 2000, the last available year in the data set. In our data-set, we adopted the municipality as the geographic unit. By using the *Code of the Administrative Division* (INE [99]), we were able to select 275 municipalities[34]. Additionally, we recur to the *Portuguese Classification of Economic Activities* at two-digit level (CAE – Rev. 2 - 15 to 37) (INE [106]) to restrict for the manufacturing sector[35]. In our research, we first considered the entire manufacturing sector, and also a division according to the number of plants (single-plant and multi-plant firms) and technological intensity (high-technology and low-technology industries).

A plant was identified as new if it was the first time it appeared in the merged data set[36]. We identified 37 222 new manufacturing plants between 1992 and 2000. The geographical and sectorial distribution of these newly created establishments are next presented:

[34] We had under consideration the change of the Code of Administrative Division in 1998 that introduced three new municipalities (Vizela, Trofa and Odivelas) and included them into the original ones, as our study is largely previous to 1998. Additionally, we excluded the islands of Azores and Madeira, as the number of new plants of the manufacturing sector born during 1992-2000 was quite small.

[35] We had under consideration the change of the Code of Economic Activity from Revision 1 to Revision 2 in 1994.

[36] We excluded possible temporary exits/errors by comparing the birth date of the plant with the age of the oldest employee.

NUTS 3, NUTS 2		New manufacturing plants										
Code	**Designation**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Total**	**%**
10101	Minho-Lima	119	79	104	84	89	109	86	92	116	878	2.36%
10102	Cávado	327	219	399	355	342	347	368	305	393	3 055	8.21%
10103	Ave	505	376	552	529	613	600	635	622	765	5 197	13.96%
10104	Grande Porto	641	487	744	517	482	449	483	413	518	4 734	12.72%
10105	Tâmega	470	368	567	363	228	569	285	616	509	3 975	10.68%
10106	Entre Douro e Vouga	246	222	353	260	222	262	248	229	217	2 259	6.07%
10107	Douro	25	64	61	42	34	30	48	50	45	399	1.07%
10108	Alto Trás-os-Montes	55	55	67	49	57	44	57	54	63	501	1.35%
101	**Região Norte**	**2 388**	**1 870**	**2 847**	**2 199**	**2 067**	**2 410**	**2 210**	**2 381**	**2 626**	**20 998**	**56.41%**
10201	Baixo Vouga	191	154	193	123	160	158	153	141	193	1 466	3.94%
10202	Baixo Mondego	80	76	92	65	69	66	64	54	101	667	1.79%
10203	Pinhal Litoral	151	127	170	114	137	141	159	153	148	1 300	3.49%
10204	Pinhal Interior Norte	55	56	62	47	49	52	48	33	56	458	1.23%
10205	Dão-Lafões	99	64	111	87	80	73	101	105	96	816	2.19%
10206	Pinhal Interior Sul	17	11	11	18	8	16	17	19	24	141	0.38%
10207	Serra da Estrela	21	11	19	16	15	20	14	14	20	150	0.40%
10208	Beira Interior Norte	35	36	45	23	22	27	28	28	30	274	0.74%
10209	Beira Interior Sul	29	13	25	21	17	27	16	26	34	208	0.56%
10210	Cova da Beira	34	31	41	22	26	21	25	27	37	264	0.71%
102	**Região Centro**	**712**	**579**	**769**	**536**	**583**	**601**	**625**	**600**	**739**	**5 744**	**15.43%**
10301	Oeste	186	137	193	126	129	138	148	144	166	1 367	3.67%
10302	Grande Lisboa	574	458	624	365	379	384	404	344	460	3 992	10.72%
10303	Península de Setúbal	225	165	226	146	155	147	172	172	188	1 596	4.29%
10304	Médio Tejo	113	63	117	61	56	64	70	70	87	701	1.88%
10305	Lezíria do Tejo	81	63	99	72	71	91	77	82	93	729	1.96%
103	**Lisboa e Vale do Tejo**	**1 179**	**886**	**1 259**	**770**	**790**	**824**	**871**	**812**	**994**	**8 385**	**22.53%**
10401	Alentejo Litoral	35	37	32	29	26	26	19	14	27	245	0.66%
10402	Alto Alentejo	45	45	40	26	24	32	25	38	31	306	0.82%
10403	Alentejo Central	58	52	62	48	41	96	57	51	71	536	1.44%
10404	Baixo Alentejo	28	36	38	31	23	33	31	27	31	278	0.75%
104	**Alentejo**	**166**	**170**	**172**	**134**	**114**	**187**	**132**	**130**	**160**	**1 365**	**3.67%**
10501	Algarve	83	71	116	74	79	68	77	83	79	730	1.96%
105	**Algarve**	**83**	**71**	**116**	**74**	**79**	**68**	**77**	**83**	**79**	**730**	**1.96%**
	Portugal (mainland)	4 528	3 576	5 163	3 713	3 633	4 090	3 915	4 006	4 598	37 222	100.00%

Source: DEEP - MTE (1991-2000), *Quadros do Pessoal*

Table 5.1. New manufacturing plants (1992-2000), by region

As we can observe, the most dynamic region is *Região Norte*, which account for more than 50% of total manufacturing plant births between 1992 and 2000. At NUTS3 level, *Grande Porto, Ave* and *Tâmega* are responsible for more than 35% of total plant births between 1992 and 2000. At the sectorial level (table 5.2), the *manufacturing of wearing apparel, dressing and dyeing of fur* and the *manufacturing of fabricated metal products (except machinery and equipment)* are responsible for more than 34% of total plant births between 1992 and 2000.

		New manufacturing plants										
CAE - Rev. 2	**Manufacturing Industry**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Total**	**%**
15	Manufacture of food products and beverages	470	435	676	409	377	439	387	375	467	4035	10.84%
16	Manufacture of tobacco	0	0	0	0	0	0	0	0	0	0	0.00%
17	Manufacture of textile	270	224	276	269	225	288	287	303	306	2448	6.58%
18	Manufacture of wearing apparel; dressing and dyeing of fur	831	544	891	785	793	847	852	832	987	7362	19.78%
19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	250	201	337	229	206	256	199	219	195	2092	5.62%
20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of straw and plaiting materials	375	307	461	348	339	382	421	371	415	3419	9.19%
21	Manufacture of paper and paper products	29	24	44	24	34	26	25	28	32	266	0.71%
22	Publishing, printing and reproduction of recorded media	258	212	322	209	215	240	226	199	281	2162	5.81%
23	Manufacture of coke, refined petroleum products and nuclear fuel	0	4	0	0	0	0	0	0	0	4	0.01%
24	Manufacture of chemicals and chemical products	50	50	79	38	32	40	40	31	43	403	1.08%
25	Manufacture of rubber and plastics products	83	63	73	46	66	47	41	56	41	516	1.39%
26	Manufacture of other non-metallic mineral products	313	231	353	239	232	272	244	274	345	2503	6.72%
27	Manufacture of basic metals	17	25	14	14	22	15	19	19	29	174	0.47%
28	Manufacture of fabricated metal products, except machinery and equipment	685	567	720	516	509	557	586	631	736	5507	14.80%
29	Manufacture of machinery and equipment n.e.c.	179	153	202	145	136	143	153	133	131	1375	3.69%
30	Manufacture of office, accounting and computing machinery	0	0	1	0	0	1	0	0	1	3	0.01%
31	Manufacture of electrical machinery and apparatus n.e.c.	58	39	51	37	45	47	31	39	34	381	1.02%
32	Manufacture of radio, television and communication equipment and apparatus	25	25	16	11	9	10	7	8	16	127	0.34%
33	Manufacture of medical, precision and optical instruments, watches and clocks	38	23	31	26	29	36	25	26	45	279	0.75%
34	Manufacture of motor vehicles, trailers and semi-trailers	15	20	33	15	15	16	15	15	22	166	0.45%
35	Manufacture of other transport equipment	18	10	24	18	29	23	31	23	23	199	0.53%
36	Manufacture of furniture; manufacturing n.e.c.	557	415	547	328	311	393	306	404	425	3686	9.90%
37	Recycling	7	4	12	7	9	12	20	20	24	115	0.31%
15-37	**Total manufacturing**	4528	3576	5163	3713	3633	4090	3915	4006	4598	37222	100.00%

Source: DEEP - MTE (1991-2000), *Quadros do Pessoal*

Table 5.2. New manufacturing plants (1992-2000), by economic activity

5.5.2 Explanatory Variables and Hypotheses

The traditional location theory suggests that the variables influencing the choice of a particular location can broadly be classified into three categories: cost variables, market variables and agglomeration economies. In this section, we intend to formulate the main hypotheses guiding our research, having under consideration empirical studies on location choice (see appendix).

The least cost theory claims that the land, labor and capital costs affect firms' decision about location. Several studies revealed that *land costs* have a negative influence on firms' decision to locate in a region. Bartik [22], Mani, Pargal and Huq[134], Figueiredo, Guimarães and Woodward [59] and Guimarães, Figueiredo and Woodward [81] used population density to evaluate land costs ([37])([38]) and concluded that its influence on location choice was negative. Similarly, Coughlin, Terza and Arrondee [46], Woodward [197] and Wu [200] used land area and concluded that its influence on the location choice was positive. Finally, some authors considered property taxes as a government policy variable that affects land costs but almost concluded for its non significance (e.g. Carlton [34], Bartik [22], Woodward [197], Coughlin and Segev [45] and Hogenbirk and Narula [94]).

Following Bartik's approach, we will adopt population density in each municipality for 1991-2001 as a proxy for *land costs* (INE [102], [108] and [110]). We may then formulate the following hypothesis:

Hypothesis 5.1 *High land costs in a municipality negatively influence new investments in that municipality.*

In their location decisions, firms are motivated by labor market conditions, in particular, labor costs and the qualifications of the workforce. *The labor cost*, measured by the average wage rate, is included in almost all studies on location choice (see appendix), while its coefficient is usually negative or non significant (except for the location decisions of foreigner firms, as a positive coefficient frequently emerges, revealing the positive effect of high wages, associated with high qualifications of the workforce, on location choice).

[37] Bartik [22] justifies this procedure as industrial and residential users compete for the same space.

[38] Other authors used *population density* as a proxy for either agglomeration economies (Wei et al [196] and Coughlin and Segev [45]) or labor market conditions (Araúzo-Carod [10] and Hogenbirk and Narula [94]).

To account for labor costs in each municipality and manufacturing sector, we recur to the real wages per working hour, for each municipality and code of economic activity (CAE) at 2-digit level (INE [106]). We used *Quadros do Pessoal* of the DEEP - MTE [50] to compute total base wages (at constant prices) and regular working hours by municipality and CAE for 1991 - 2000. We then consider the following hypothesis:

Hypothesis 5.2 *High labor costs in a municipality negatively influence new investments in that municipality*

Several researchers considered the *unemployment rate* as affecting firms' location choice (e.g. Carlton [34], Friedman, Gerlowski and Silberman [61], Woodward [197], Shaver [175], Head, Ries and Svenson [88], Coughlin and Segev [45], Head and Mayer [87] and Hogenbirk and Narula [94]). However, the impact of unemployment on the location decision is not completely clear. On one hand, high unemployment rates can signal low demand or the lack of suitable employees. On the other hand, it may indicate available workforce, possibly, at a low cost. Additionally, the effects of the unemployment rate on firms' location may be biased, due to the influence of government policies that are, in UE countries, mainly employment oriented. For these reasons, we decided to avoid this variable in our study.

Other scholars make use of *unionization rates* as a characteristic of the labor market that might influence location decisions (e.g. Bartik [22], Schmenner, Huber and Cook [173], Coughlin, Terza and Arrondee [46], Friedman, Gerlowski and Silberman [61], Woodward [197], Shaver [175], Head, Ries and Svenson [88] and Coughlin and Segev [45]). The point is that low unionization rates may attract firms as it allows them to pursue profit maximization unencumbered by union activities and contract restrictions. However, and as the institutional framework with respect to labor market legislation is invariant across Portuguese municipalities, we did not considered this variable.

Labor productivity is also considered in some studies, either if measured directly (e.g. Friedman, Gerlowsky and Silberman [61] and Woodward [197]) or by considering the skill level of employees (Hansen [85], Kittiprapas and McCann [123], Guimarães, Figueiredo and Woodward [79]) and Holl [95]]. When having under consideration the issue of the location choice determinants, the focus on the qualifications of the population seems to be more adequate. Therefore, some authors considered the influence of specific skills on location choice [e.g. number of engineers (Carlton [34])], or, more often, the education level of population (e.g. Bartik [22], Woodward [197] and Pusterla and Resmini [166]) or even the influence of high-degree education (Coughlin and Segev [45], Cheng and Kwan [38] and Araúzo-Carod [10]).

In this work, we used the *average years of schooling of the adult population* as a proxy for *human capital* stock in each municipally. By this procedure, we intend to capture the population skills and abilities that affect the productivity of the workforce. We computed the average years of schooling of the adult population for each municipality, according to the methodology of Barro and Lee [21]:

$$H = \frac{1}{n}\sum_{g=1}^{9}\left[D_g.(n_g|c) + \frac{D_g + D_{g-1}}{2}.(n_g|i) + D_{g-1}.(n_g|a)\right]$$

where

n = Population with age 25 to 64

$n_g|c$ = Population with age 25 to 64 with education level g (complete)

$n_g|i$ = Population with age 25 to 64 with education level g (incomplete)

$n_g|a$ = Population with age 25 to 64 with education level g (attendance)

D_g = Number of schooling years that corresponds to each education level g

The implementation of this methodology was made in few but arduous steps. First, we compile statistical information about the number of individuals with age 25 to 64 ([39]) that attained the various education levels for each municipality in 1991 (INE [101]) and 2001 (INE [108]). Then, we pondered the number of individuals that attained each education

[39]The availability of statistical information motivated the choice of this age cohort, which account for about 86% of the active population in 2001 in Portugal (INE [107]).

level with the corresponding schooling years, D_g, having under consideration Portuguese legislation on the Education System [52] and the International Standard Classification of Education (ISCED) [152]. We then considered the following education levels: $g = 1$ corresponds to the primary-1st cycle, with a duration of 4 years ($D_1 = 4$); $g = 2$ corresponds to the primary - 2nd cycle (or ISCED level 1), with a duration of 2 years ($D_2 = 6$); $g = 3$ is the primary - 3rd cycle (or ISCED level 2), with a duration of 3 years ($D_3 = 9$); $g = 4$ corresponds to secondary education (or ISCED level 3), with a duration of 3 years ($D_4 = 12$); $g = 5$ corresponds to post-secondary non-tertiary education (or ISCED 4), with, in general, a duration of 1 schooling year ($D_5 = 13$); $g = 6$ corresponds a Bachelor's degree (ISCED level 5B) with, usually, a duration of 3 years ($D_6 = 15$); $g = 7$ corresponds to an under-graduate degree (ISCED 5A), with, usually, a duration of 4 or 5 years ($D_7 = 16$); $g = 8$ corresponds to Master degree, with, usually, a duration of 1 schooling year ($D_8 = 17$); finally, $g = 9$ corresponds to a Ph.D. degree (ISCED level 6), with a duration of 2 or more schooling years ($D_9 = 18$).

Additionally, and in order to take into account if individuals complete or not the corresponding education level, we presumed that if an individual complete an education level g, then its ponderer will be D_g. Alternatively, if an individual was attending at an education level g, then its ponderer will be D_{g-1}. Finally, if an individual did not complete an education level g, then its ponderer will be $\frac{D_g+D_{g-1}}{2}$.

After computing the human capital stock for each municipality in 1991 and 2001, we estimated the human capital stock between these years by computing the average annual rate of growth of the human capital stock between 1991 and 2001 ([40]).

Although we would expect that the sign of the human capital coefficient to be positive, there is no clear evidence of such fact, as we may conclude from previous studies (see appendix). Nevertheless, we will formulate the following hypothesis:

Hypothesis 5.3 *High human capital stock in a municipality positively influences new investments in that municipality.*

[40] Alternatively, the human capital stock could be introduced at the regional level (NUTS3), but some local specificities could be lost. Also, we computed the *human capital potential* for each municipality, but results were quite similar.

Several studies use corporate taxes (or other local taxes) to evaluate *capital costs*' influence on location choice (e.g. Carlton [34], Bartik [22], Friedman, Gerlowski and Silberman [61], Woodward [197], Shaver [175], Head, Ries and Svenson [88] and Head and Mayer [87]), whilst its expected coefficient is often non significant.

In our research, capital costs are measured by the taxes over companies collected by municipalities, which include both *derrama*[41] and other taxes over firms. We first collected information about local finances near *Direcção-Geral das Autarquias Locais* [51] for the period 1991-2001. Then, the local taxes were deflated by using the *Consumer Price Index* (INE [103]). Afterwards, we divide it by the number of societies in each municipality (INE [104]). We then consider the following hypothesis:

Hypothesis 5.4 *High capital costs in a municipality negatively influence new investments in that municipality.*

Another strand of the literature focus on the influence of demand variables on the location choice. The *market size*, measured by per capita income, is frequently included in location studies (e.g. Coughlin, Terza and Arrondee [46], Coughlin and Segev [45], Cheng and Kwan [38], Guimarães, Figueiredo and Woodward [81] and Hogenbirk and Narula [94]). Alternatively, some scholars used the gravitation personal income as a proxy for the *potential market*, as it intends to capture both market size and its accessibility (e.g. Friedman, Gerlowski and Silberman [61], Woodward [197] and Head and Mayer [87]). Finally, others simply use residential population [e.g. Holl [95]]

In order to capture the influence of market size on location choice, we considered two variables: we first considered the *Purchasing Power Index*[42] for each municipality between 1993-2002 (INE [105]), which intends to capture the influence *local market* size on location choice. Alternatively, and having under consideration the small size of most

[41] The municipal surcharge (*derrama*) is a local municipal tax that can be charged annually by municipal authorities up to maximum of 10% of the amount paid in corporate tax (IRC).

[42] The *Purchasing Power Index* (IPPC) intends to capture the purchasing power in each municipality. It is an index built by means of a model of factorial analysis and recurring to a set of 20 variables that were selected according to an expenditure criteria upon a larger group of 70 variables (INE [111]).

portuguese municipalities, we used the *per capita Gross Domestic Product* at regional level NUTS3 for 1992-2000 as a proxy for the *regional market* size (INE [100]).

Most studies conclude for the positive influence of market size on location choice, which stimulate us to express the following hypotheses:

Hypothesis 5.5 *High regional market size positively influences new investments in a municipality.*

Hypothesis 5.6 *High local market size positively influences new investments in a municipality.*

Additionally, some authors consider the influence of *market accessibility* on firms' location decision, by introducing the geographical or time distance to an important market (city center or capital) or to an airport or port [e.g. Hansen [85], Wu [199], Guimarães, Figueiredo and Woodward [79], Wu [200], Araúzo-Carod [10], Figueiredo, Guimarães and Woodward [59] and Holl [95]]. Therefore, we employ the minor physical distance between each municipality to Porto or Lisbon[43] as a proxy for the accessibility of each municipality (INE [109]). Having under consideration previous studies, we expect to confirm the following hypothesis:

Hypothesis 5.7 *High distance to Porto or Lisbon in a municipality negatively influences new investments in that municipality.*

Both location theory and empirical studies claim for the relevance of *agglomeration economies*. Literature usually distinguishes between *urbanization economies*, which are external to firms and industries but internal to a city (e.g. access to large population centres and large and diversified service and manufacturing sectors) and *localization economies*, which are external to firms but internal to an industry (e.g. access to specialized labor force and communication economies).

[43]Porto and Lisbon (capital) are the most important cities in Portugal, both equipped with international airport, port and railway stations.

Nearly all studies concluded for the positive influence of *localization economies* on location choice, usually measured by the number of firms or employment in each manufacturing sector (e.g. Hansen [85], Guimarães, Figueiredo and Woodward [79], Barrios, Görg and Strobl [20], Head and Mayer [87], Guimarães, Figueiredo and Woodward [81] and Hogenbirk and Narula [94]) or by an industrial diversity index (e.g. Araúzo-Carod [10], Holl [95] and Pusterla and Resmini [166]).

In what concerns *urbanization economies*, some researchers used a measure of global industrial activity in the region (e.g. Carlton [34], Bartik [22], Coughlin, Terza and Arrondee [46], Woodward [197], Mani, Pargal and Huq [134], Guimarães, Figueiredo and Woodward [79], Araúzo-Carod [10] and Barrios, Görg and Strobl [20]), while others use an indicator of the economic activity size, such as per capita income, population size or density of industrial and services activities (e.g. Shaver [175], Wei et al [196], Coughlin and Segev [45] and Guimarães, Figueiredo and Woodward [81]). The relevance of urbanization economies was, in most cases, demonstrated.

In our research, we account for *localization economies* by considering the share of manufacturing employment for each CAE - 2 digit in each municipally for 1991-1999 (DEEP - MTE [50]). *Urbanization economies* are measured by the density of manufacturing and service plants (CAE D, G, H, I, J, K) per square kilometer in each municipally for 1991-2000 (DEEP - MTE [50] and INE [110]). We then expect to observe:

Hypothesis 5.8 *High localization economies in a municipality positively influence new investments in that municipality.*

Hypothesis 5.9 *High urbanization economies in a municipality positively influence new investments in that municipality.*

In addition to traditional location determinants, we add the Research and Development (R&D) per capita expenditures at the municipality level. To our knowledge, few studies introduced R&D variables in location studies (e.g. Wei et al [196] and Woodward, Figueiredo and Guimarães [198]). Having under consideration the composition of R&D

expenditures and its geographical distribution[44], we would expect to observe a small impact of the R&D expenditures on location choice, but higher when considering the high-tech sample.

For our purpose, we first collect information on R&D expenditures at the municipality level for 1995 - 2001 by using a biannual national inquiry (OCES [147])[45]. Then, R&D expenditures were deflated (INE [103]) and, for the missing years, we averaged the nearest years. Finally, we divide it by total inhabitants in each municipality (INE [102] and [108]) ([46])([47]). We then expect to demonstrate the following hypothesis:

Hypothesis 5.10 *High R&D expenditures in a municipality positively influence new investments in that municipality.*

Finally, and in order to control for unobservable region characteristics that might affect firms' location choice, we included dummy variables for each region NUTS (*Nomenclature of Territorial Units for Statistics*) at 3-digit level[48].

Table 5.3 summarizes main information about explanatory variables:

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[44] In Portugal, and for the year 1999, about 66.5% of the R&D expenditure was made by the Government and High Education sector (OCES [147]).

[45] The *Scientific and Technological National Potential Survey* (IPCTN) is carried out every two years by the *National Observatory of Science and Technology* (OCES). The conceptual and methodological model of the IPCTN agrees with the *Frascati Manual* [149]. In what concerns the R&D data, the inquiry covers both the R&D expenditures carried out on the national territory in the year concerned and also the R&D personnel, expressed in full-time equivalent. In Portugal, the census of the number of researchers affected to R&D activities involves some difficulties, as there is some subjectivity on the evaluation of the percent of time dedicated to research when the R&D units coexist with other activities (e.g. universities). The survey covers four sectors of performance of R&D - High Education, Government, Business Enterprise and Private Non-Profit Institutions. It comprises R&D in both natural sciences, engineering, social sciences and humanities. R&D expenditures are divided into five sources of funds, from High Education, Government, Business Enterprise, Private Non-Profit Institutions and abroad (OCES [148]).

[46] We also used the *potential R&D* for each municipality, but no improvements were observed.

[47] In spite of being optimal to use R&D stock, we recurred to R&D flow, which is highly correlated to R&D stock.

[48] Alternatively, we considered dummies at NUTS 2-digit, but a lot of statistical information at the local level would be lost.

Variable	Proxy	Expected sign	Data Source
Land costs	Population density, by municipality, 1992-2001	Negative	INE (1991-2000), *Estimativas Definitivas da População Residente;* INE (2001b), *Recenseamento Geral da População e Habitação (Resultados Definitivos);* INE (2003b), *Referenciação Territorial*
Labor costs	Real base-wage over regular working hours, by municipality and CAE, 1992-2000	Negative	DEEP-MTE (1991-2000), *Quadros do Pessoal*
Human capital	Average years of schooling of the adult population, by municipality, 1992-2000	Positive	INE (1991), Recenseamento Geral da População e Habitação (Resultados Definitivos); INE (2001), Recenseamento Geral da População e Habitação (Resultados Definitivos)
Capital costs	Derrama plus other taxes over firms divided by total societies, by municipality, 1992-2000	Negative	DGAL (1991-2001), *Finanças Municipais;* INE (1992-2001), *Ficheiro Central de Empresas e Estabelecimentos*
Regional market	Per capita Gross Domestic Product, by NUTS3, 1992-2000	Positive	INE (1990-2002), *Contas Regionais*
Local market	Purchasing Power Index (IPPC), by municipality, 1993-2002	Positive	INE (1993-2002), *Estudo sobre o Poder de Compra Concelhio*
Market accessibility	Minor geographical distance to Porto/Lisbon, by municipality	Negative	INE (2003), *Base Geográfica de Referenciação da Informação*
Localization economies	Share of manufacturing employment for each CAE - 2 digit, by municipality, 1991-1999	Positive	DEEP-MTE (1991-2000), *Quadros do Pessoal*
Urbanization economies	Density of manufacturing and service plants (CAE D, G, H, I, J, K) per square kilometer, by municipality, 1992-2000	Positive	DEEP-MTE (1991-2000), *Quadros do Pessoal;* INE (2003b), *Referenciação Territorial*
R&D	R&D expenditures per capita, by municipality, 1994-2002	Positive	OCES (1995, 1997, 1999, 2001), *Inquérito ao Potencial Científico e Tecnológico;* INE (1991-2000), *Estimativas Definitivas da População Residente;* INE (2001), *Recenseamento Geral da População e Habitação (Resultados Definitivos)*

Table 5.3. Explanatory variables

5.6 Empirical Results

In order to evaluate the importance of traditional and technological determinants for location choice, we considered three data sets: first, we used total new manufacturing plants; second, we make difference between the single-plant and the multi-plant's location decisions; finally, and by using OECD classification of industrial's technological intensity [151], we considered two data sets: the new plants that are *low and medium-low* technology intensive and the new plants that are *high and medium-high* technology intensive.

We modelled the location choice of new manufacturing plants between 1992-2000 within 275 municipalities through a discrete choice analysis. We take advantage of the equivalence between the conditional logit model and the Poisson regression by using a set of dummy variables for each combination of year and CAE 2-digit. Additionally, if data contains overdispersion, the negative binomial model will be taken under consideration.

5.6.1 Total New Manufacturing Plants

Empirical results with respect to location choice of new manufacturing plants are presented in Table 5.4. Regressions[49] (1) and (2) respect to a standard CLM by means of its equivalence with Poisson model, which is guaranteed by using a set of dummy variables for each combination of year and 2-digit CAE sector. Differences in both regressions are due to the use of either a regional or a local market variable. Similarly, regressions (3) and (4) respects to a CLM regression but includes a set of dummy variable for each region NUTS3. In order to more effectively control for the potential violation of IIA assumption, we estimated a Poisson panel regression with either random or fixed effects by municipality [regressions (5) to (10)]. All explanatory variables are included in their logarithmic form.

As we can observe, estimation results of regression (1) to (4) are quite similar. All variables are highly significant and with the expected signs, except for human capital, local market and capital costs. We find evidence that production costs had a significant and negative impact on location choice, except for capital costs. The regional market size has a significant and positive impact on location choice, while the local market size has a sign contrary to a priori expectation. Also, the municipalities' accessibility to main markets is significant and with the expected sign. Additionally, our results reveal that the most important location determinants are the agglomeration economies, namely, the urbanization economies, which accords with existing literature. On the opposite side, the R&D variable has the smallest impact on location choice. As it was expected, the inclusion of the region dummy variable in regressions (3) and (4) improve the overall significance, as it

[49] Our methodological approach was motivated by Guimarães, Figueiredo and Woodward [81].

	POISSON MODEL									
	With dummy by year*CAE		**With dummies by year*CAE and NUTS3**		**With random effects by municipality and dummy by year*CAE**		**With random effects by municipality and dummies by year*CAE and NUTS3**		**With fixed effects by municipality and dummy by year*CAE**	
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Land costs	-0.596*	-0.608*	-1.188*	-1.190*	-0.962*	-0.957*	-1.032*	-1.029*	0.001	-0.023
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.998)	(0.941)
Labor costs	-0.913*	-0.787*	-0.866*	-0.864*	-1.088*	-1.078*	-1.079*	-1.073*	-1.096*	-1.089*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Human capital	-2.357*	-1.590*	-0.830*	-0.806*	-0.754*	-0.503	-0.535	-0.453	-0.720	-0.626
	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)	(0.082)	(0.088)	(0.153)	(0.058)	(0.100)
Capital costs	0.050*	0.053*	0.065*	0.065*	-0.008	-0.004	-0.005	0.001	-0.018	-0.011
	(0.000)	(0.000)	(0.000)	(0.000)	(0.600)	(0.825)	(0.751)	(0.968)	(0.298)	(0.529)
Regional market	0.440*	---	0.212	---	0.434*	---	0.599*	---	0.680*	---
	(0.000)	---	(0.261)	---	(0.004)	---	(0.002)	---	(0.001)	---
Local market	---	-0.233*	---	-0.018	---	-0.074	---	-0.062	---	-0.121
	---	(0.000)	---	(0.617)	---	(0.303)	---	(0.401)	---	(0.106)
Market accessibility	-0.116*	-0.141*	-0.208*	-0.209*	-0.203	-0.220*	-0.036	-0.037	---	---
	(0.000)	(0.000)	(0.000)	(0.000)	(0.080)	(0.053)	(0.842)	(0.838)	---	---
Localization economies	0.722*	0.714*	0.722*	0.722*	0.739*	0.739*	0.739*	0.739*	0.742*	0.741*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urbanization economies	1.069*	1.089*	1.295*	1.298*	1.339*	1.351*	1.402*	1.399*	1.476*	1.470*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R&D	0.059*	0.060*	0.044*	0.049*	0.008	0.008	0.009	0.009	0.005	0.006
	(0.000)	(0.000)	(0.000)	(0.000)	(0.272)	(0.266)	(0.190)	(0.199)	(0.441)	(0.434)
Constant	11.113*	14.020*	13.175*	14.949*	11.664*	15.225*	9.032*	14.004*	---	---
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	---	---
Number of obs.	14332	14332	14332	14332	14332	14332	14332	14332	14323	14323
Log likelihood	-25451.19	-25514.69	-22755.42	-22755.93	-19480.92	-19484.65	-19448.55	-19452.87	-18583.05	-18587.75
Pseudo R^2	0.5165	0.5153	0.5677	0.5677						
LR test	54370.89	54243.88	59762.42	59761.41						
	(0.000)	(0.000)	(0.000)	(0.000)						
Pearson statistic	48886.8	49203.33	41550.2	41563.41						
	(0.000)	(0.000)	(0.000)	(0.000)						
Wald test					27088.84	27081.16	27200.57	27198.29	26766.75	26763.27
					(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: p-values are in parentisis
* significant at 0.05 level of significance

Table 5.4. Total new manufacturing plants (1992-2000): Poisson model

can be deduced from the increase of the log likelihood, the likelihood-ratio index or the "$pseudo - R^2$".

In order to more effectively control for the IIA assumption violation, we then consider specific-effects by municipality, either random or fixed. We first introduced specific random effects by municipality through a Poisson panel regression with or without dummies by region [regressions (5) to (8)]. We then observe an increase of the corresponding log-likelihood of the random effects model when comparing with the corresponding Poisson regression, which maintains the hypothesis of random effects by municipality. At the same time, the results remain quite similar, except for the R&D variable, which loses significance. Alternatively, we performed a Poisson regression with fixed effects by municipality [regressions (9) and (10)], with some perceptible changes in results. Actually, on the costs side only labor costs maintain its significance, while on the demand side market accessibility loses relevance. Agglomeration economies are still significant and with the predicted sign.

However, the Pearson statistics for the goodness of fit lead us to reject the hypothesis that the variance equals to the mean at 1 percent of significance. Therefore, it reveals that the Poisson regression is not adequate to our data, suggesting that we should try the negative binomial model. Table 5.5 resumes main results from our estimation.

As before, we ran several models, which performed quite well, as we can observe from the log-likelihood, likelihood-ratio and Wald tests. Additionally, the likelihood-ratio test of $\alpha = 0$ indicates that the probability of observing this data conditional to a Poisson distribution is nearly zero, which confirms that the negative binomial model is more suitable. We started with a simple negative binomial regression with a set of dummies for each combination of year and 2-digit CAE sector [regressions (11) and (12)] and included a dummy variable for each region NUTS3 [regressions (13) and (14)] in order to capture other regions' characteristics that might affect firms' location choice. Finally, we estimated a negative binomial panel regression with either random or fixed effects by municipality, with or without dummies for region [regressions (15) to (22)][50].

Let us consider the negative binomial model without "specific-effects" by municipalities [regressions (11) to (14)]. As we can observe, some variables have a very regular behavior across regressions: land and labor costs and agglomeration economies are always significant and with the expected signs. On the other side, capital costs and human capital are almost never significant or with the correct sign. Demand variables are usually significant and with the expected sign. The regional market variable has a positive and significance influence on location choice, except when dummies for region are included, while local market is always significant and with the predicted sign. Additionally, the municipalities' accessibility is also significant and with the expected sign. The R&D variable is signifi-

[50] We may note that the coefficients estimated for the Poisson and for the negative binomial model are quite similar.

	NEGATIVE BINOMIAL MODEL											
	With dummy by year*CAE		With dummies by year*CAE and NUTS3		With random effects by municipality and dummy by year*CAE		With random effects by municipality and dummies by year*CAE and NUTS3		With fixed effects by municipality and dummy by year*CAE		With fixed effects by municipality and dummies by year*CAE and NUTS3	
Variables	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
Land costs	-0.692*	-0.627*	-1.060*	-1.003*	-0.480*	-0.466*	-0.491*	-0.494*	-0.591*	-0.589*	-0.467*	-0.472*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.005)	(0.004)
Labor costs	-0.644*	-0.607*	-0.637*	-0.647*	-0.872*	-0.859*	-0.869*	-0.863*	-0.850*	-0.837*	-0.857*	-0.852*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Human capital	-0.992*	-1.097*	0.009	-0.310	2.297*	2.383*	0.558	0.573	2.864*	3.105*	0.237	0.277
	(0.000)	(0.000)	(0.953)	(0.088)	(0.000)	(0.000)	(0.083)	(0.082)	(0.000)	(0.000)	(0.493)	(0.429)
Capital costs	0.014	0.015	0.029*	0.031*	-0.018	-0.012	-0.028	-0.022	-0.032	-0.021	-0.034	-0.028
	(0.303)	(0.282)	(0.039)	(0.026)	(0.358)	(0.539)	(0.165)	(0.267)	(0.120)	(0.290)	(0.103)	(0.172)
Regional market	0.288*	---	0.291	---	0.592*	---	0.465*	---	0.734*	---	0.435	---
	(0.000)	---	(0.326)	---	(0.000)	---	(0.052)	---	(0.000)	---	(0.066)	---
Local market	---	0.227*	---	0.249*	---	0.287*	---	0.002	---	0.307*	---	-0.035
	---	(0.002)	---	(0.001)	---	(0.002)	---	(0.983)	---	(0.002)	---	(0.688)
Market accessibility	-0.149*	-0.170*	-0.205*	-0.201*	-0.071	-0.113	-0.314*	-0.322*	-0.136	-0.182*	-0.564*	-0.571*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.328)	(0.117)	(0.027)	(0.023)	(0.127)	(0.041)	(0.001)	(0.001)
Localization economies	0.525*	0.526*	0.531*	0.532*	0.571*	0.569*	0.545*	0.544*	0.556*	0.554*	0.532*	0.531*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urbanization economies	1.096*	1.031*	1.150*	1.085*	0.506*	0.484*	0.711*	0.705*	0.392*	0.384*	0.663*	0.663*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R&D	0.029*	0.027*	0.047*	0.044*	0.012	0.010	0.022*	0.022*	0.012	0.009	0.019*	0.019*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.161)	(0.257)	(0.015)	(0.016)	(0.201)	(0.307)	(0.045)	(0.042)
Constant	8.848*	10.06*	9.164*	10.80*	1.971	5.625*	7.031*	10.81*	0.812	5.367*	8.846*	12.49*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.130)	(0.000)	(0.002)	(0.000)	(0.566)	(0.000)	(0.000)	(0.000)
Number of obs.	14332	14332	14332	14332	14332	14332	14332	14332	14323	14323	14323	14323
Log likelihood	-19689.8	-19699.1	-19160.9	-19155.7	-18639.2	-18645.6	-18536.3	-18538.2	-17704.1	-17713.6	-17559.5	-17561.1
Pseudo R^2	0.1949	0.1945	0.2165	0.2167								
LR test	9530.95	9512.38	10588.7	10599.1								
	(0.000)	(0.000)	(0.000)	(0.000)								
Likelihood-ratio test of alpha=0	12000	12000	7189.05	7200.47								
	(0.000)	(0.000)	(0.000)	(0.000)								
Wald test					8922.58	8904.79	9212.34	9203.24	8856.01	8837.73	9242.52	9236.61
					(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: p-values are in parentisis
* significant at 0.05 level of significance

Table 5.5. Total new manufacturing plants (1992-2000): Negative binomial model

cant but has the smallest elasticity: we estimate that, everything else constant, a 1 percent increase in urbanization economies leads to about 1.1 percent increase in the number of new plants, while the same elasticity for the R&D variable is about 0.03-0.04. The inclusion of dummy variables by region is supported by the increase of the log-likelihood or the "$pseudo - R^2$".

We then consider "specific-effects" by municipalities through a negative binomial regression with either random or fixed effects [regressions (15) to (22)]. The difference in the log-likelihoods between the model with specific-effects and the one without specific-effects is statistically significant and provides evidence that the inclusion of specific effects is convincing. At the same time, the inclusion of dummy variables by region is supported by the increase of the log-likelihood, which gives reason for the existence of regional characteristics that are not captured by other variables. Likewise, the inclusion of the regional market, instead of the local market, is consistent with the increase of the overall significance.

In order to test for the inclusion of random or fixed effects by municipality, we performed an Hausman test, which tests the null hypothesis that the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator. We compared regressions (17) and (21) and the resulting statistic equals 0.71, which lead us to not reject the null hypothesis at 1 percent level of significance. Therefore, our results supports the hypothesis of random specific effects by municipality.

Focusing on regression (17), we may then conclude that the most relevant determinants for location choice are the labor and land costs and urbanization and localization economies. In fact, we estimated that, everything else constant, a 1 percent increase in urbanization or localization economies leads to about a 0.71 or 0.55 percent increase in the number of new plants, respectively. These results are supported by several empirical studies [e.g. Carlton [34], Hansen [85], Coughlin, Terza and Arrondee [46], Woodward [197], Guimarães, Figueiredo and Woodward [79], Head and Mayer [87]]. Comparable elasticities with respect to labor and land costs are 0.87 and 0.49, respectively. The negative influence of labor costs on location choice is evidenced in several studies [e.g. Coughlin, Terza and Arrondee [46], Friedman, Gerlowski and Silberman [61], Coughlin and Segev [45], Cheng and Kwan [38], Guimarães, Figueiredo and Woodward [81] and Pusterla and Resmini [166]]. At the same time, few authors confirmed the significance and negative influence of land costs [e.g. Mani, Pargal and Huq [134] and Guimarães, Figueiredo and Woodward [81]]. On the contrary, capital costs are never statistically significant, which can be justified by the absence of noteworthy differences in the cost of capital across Portuguese municipalities. This result is also confirmed in several studies [e.g. Carlton [34], Woodward [197], Shaver [175] and Head and Mayer [87]]. The lack of consistency of results of the human capital variable may be justified by the aggregate nature of the indicator, which does not allow one to evaluate the importance of some specific skills (e.g. engineers) for the location choice. Our result is supported by several other empirical studies (e.g. Kittiprapas and McCann [123], Guimarães, Figueiredo and Woodward [79], Araúzo-Carod [10] and Pusterla and Resmini [166]).

On the demand side, we observed that the regional market size and the accessibility to main markets and infrastructures have a significant and positive influence on location choice, which can be justified by the small size of most municipalities. These results are confirmed by several studies [e.g. Coughlin, Terza and Arrondee [46], Friedman, Gerlowski and Silberman [61], Head, Ries and Swenson [88], Cheng and Kwan [38], Guimarães, Figueiredo and Woodward [79], Araúzo-Carod [10] and Head and Mayer [87]].

Finally, the R&D variable has a significant and positive influence on location choice, which evidences the presence of R&D spillovers. However, its elasticities is the lowest one: in fact, we estimated that, a 1 percent increase in per capita R&D expenditures leads to about 0.02 percent increase in the number of new plants.

Our results find confirmation in previous studies for the Portuguese case[51]. In fact, Figueiredo, Guimarães and Woodward [59] also find that the agglomeration economies, labor and land costs are the most important determinants for firms' location choice, while capital costs were not significant. Also, Holl [95] find relevance for the labour cost variable, while agglomeration economies appeared to be non-significant for the location decision. These scholars also claim the relevance of both market size and market accessibility for location choice. Besides, in our study we distinguish between the regional and the local market but our results only support the importance of the regional market for the location choice. Our research also confirms the importance of the R&D activities for firms' location choice, which was not considered in previous studies.

[51]We restricted for the studies that used discrete choice modeling to evaluate the location decision of new domestic plants, which are about 99,4% of total new plants in Portugal. Additionally, we excluded other studies that used the survey method, such as Reis [167] and Santos [172].

5.6.2 Multi-plants and Single-plants

Previous results show data in an aggregated way, without considering that start-ups differ in features such as its size, technological intensity, sectorial characteristics or country of origin. Literature on location choice have stressed the relevance of capital structure by focusing on decisions made by foreigner and domestic firms [e.g. Friedman, Gerlowski and Silberman [61], Woodward [197], Shaver [175], Head, Ries and Swenson [88], Coughlin and Segev [45] and Guimarães, Figueiredo and Woodward [79], among others]. Also, some scholars claim that firms' location choice is influenced by its size (e.g. Araúzo-Carod and Manjón-Antolín [11]), firms' industrial activity (e.g. Araúzo-Carod [10] and Barrios, Görg and Strobl [20]), or entrepreneur's preference for the home base (e.g. [59]).

In this section, we examine another feature that has received less attention in literature: new single-plants and new multi-plants location choices. This distinction is important because location decisions are taken on the grounds of incomplete information. We might expect that multi-plants have access to more information about sites than single-plants when they make their location's decisions. Also, multi-plants might benefit from economies of scale or from a more matured entrepreneurship. Therefore, and as the birth of single-plant or a multi-plant results from two different spatial decision-making processes, they should be treated separately.

We then aim at evaluate how sectorial and geographical characteristics affect single-plant and multi-plant's location decisions. We were able to identify 37 222 new starting plants between 1992-2000, from which 89,35% were new single-plants and 10,65% were new multi-plants. Geographical location of new single-plants and multi-plants is presented in table 5.6.

As we can observe, there is a strong evidence that single-plants and multi-plants locate differently: single-plants concentrate in *Região Norte*, while multi-plants distribute between *Região Norte* and *Lisboa and Vale do Tejo*.

We modelled the location choice of new single-plants and new multi-plants through a conditional logit model by means of its equivalence with Poisson model, which is guaranteed

NUTS 3, NUTS 2		New Single-Plants (1992-2000)		New Multi-Plants (1992-2000)	
Code	Designation	Total	%	Total	%
10101	Minho-Lima	774	2.33%	104	2.62%
10102	Cávado	2 850	8.57%	205	5.17%
10103	Ave	4 863	14.62%	334	8.43%
10104	Grande Porto	4 211	12.66%	523	13.19%
10105	Tâmega	3 808	11.45%	167	4.21%
10106	Entre Douro e Vouga	2 146	6.45%	113	2.85%
10107	Douro	348	1.05%	51	1.29%
10108	Alto Trás-os-Montes	457	1.37%	44	1.11%
101	**Região Norte**	**19 457**	**58.50%**	**1 541**	**38.87%**
10201	Baixo Vouga	1 342	4.04%	124	3.13%
10202	Baixo Mondego	565	1.70%	102	2.57%
10203	Pinhal Litoral	1 167	3.51%	133	3.36%
10204	Pinhal Interior Norte	423	1.27%	35	0.88%
10205	Dão-Lafões	747	2.25%	69	1.74%
10206	Pinhal Interior Sul	132	0.40%	9	0.23%
10207	Serra da Estrela	143	0.43%	7	0.18%
10208	Beira Interior Norte	242	0.73%	32	0.81%
10209	Beira Interior Sul	176	0.53%	32	0.81%
10210	Cova da Beira	231	0.69%	33	0.83%
102	**Região Centro**	**5 168**	**15.54%**	**576**	**14.53%**
10301	Oeste	1 225	3.68%	142	3.58%
10302	Grande Lisboa	3 233	9.72%	759	19.15%
10303	Península de Setúbal	1 274	3.83%	322	8.12%
10304	Médio Tejo	599	1.80%	102	2.57%
10305	Lezíria do Tejo	624	1.88%	105	2.65%
103	**Lisboa e Vale do Tejo**	**6 955**	**20.91%**	**1 430**	**36.07%**
10401	Alentejo Litoral	185	0.56%	60	1.51%
10402	Alto Alentejo	242	0.73%	64	1.61%
10403	Alentejo Central	421	1.27%	115	2.90%
10404	Baixo Alentejo	237	0.71%	41	1.03%
104	**Alentejo**	**1 085**	**3.26%**	**280**	**7.06%**
10501	Algarve	593	1.78%	137	3.46%
105	**Algarve**	**593**	**1.78%**	**137**	**3.46%**
	Portugal (mainland)	33 258	100.00%	3 964	100.00%

Source: DEEP - MTE (1991-2000), *Quadros do Pessoal*

Table 5.6. New single and multi-plant firms (1992-2000), by region

by using a set of dummy variables for each combination of year and 2-digit CAE sector. Additionally, we estimated a CLM with a set of dummy variables for regions (NUTS3) in order to capture the influence of other non-observable variables. Results are presented in table 5.7.

As we can observe, location factors that affect single-plants and multi-plants act differently. In fact, while some location factors have a similar performance (land and labor costs, agglomeration economies and R&D are always significant and with the expected sign; capital costs never have the expected sign), we may identify different features. In fact, labor costs, urbanization and localization economies have always higher elasticities

	SINGLE-PLANT FIRMS				MULTI-PLANT FIRMS			
	Poisson model				Poisson model			
	With dummy by year*CAE		With dummies by year*CAE and NUTS3		With dummy by year*CAE		With dummies by year*CAE and NUTS3	
Variables	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
Land costs	-0.599*	-0.615*	-1.198*	-1.207*	-0.656*	-0.493*	-1.130*	-0.992*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Labor costs	-1.003*	-0.868*	-0.926*	-0.924*	-0.382*	-0.314*	-0.536*	-0.561*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.006)	(0.000)	(0.000)
Human capital	-2.742*	-1.866*	-1.064*	-0.990*	0.549*	0.309	0.744*	0.052
	(0.000)	(0.000)	(0.000)	(0.000)	(0.007)	(0.216)	(0.005)	(0.872)
Capital costs	0.051*	0.054*	0.064*	0.065*	0.072*	0.074*	0.072*	0.072*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.003)	(0.009)	(0.008)
Regional market	0.472*	---	0.130	---	0.406*	---	0.039	---
	(0.000)	---	(0.522)	---	(0.000)	---	(0.942)	---
Local market	---	-0.271*	---	-0.054	---	0.386*	---	0.604*
	---	(0.000)	---	(0.147)	---	(0.001)	---	(0.000)
Market accessibility	-0.116*	-0.141*	-0.226*	-0.225*	-0.135*	-0.165*	-0.075	-0.079
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.283)	(0.258)
Localization economies	0.747*	0.738*	0.744*	0.743*	0.498*	0.499*	0.534*	0.538*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urbanization economies	1.099*	1.125*	1.311*	1.323*	0.887*	0.718*	1.206*	1.038*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R&D	0.059*	0.060*	0.047*	0.047*	0.066*	0.061*	0.078*	0.071*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	11.857*	14.987*	14.522*	15.711*	1.527*	2.694*	7.364	5.832*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.134)	(0.004)	(0.102)	(0.000)
Number of obs.	14332	14332	14332	14332	14332	14332	14332	14332
Log likelihood	-23517.82	-23575.48	-21093.24	-21092.42	-6386.72	-6389.46	-6104.79	-6094.89
Pseudo R^2	0.5259	0.5247	0.5748	0.5748	0.2260	0.2256	0.2601	0.2613
LR test	52168.80	52053.48	57017.96	57019.61	3729.18	3723.68	4293.03	4312.83
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pearson statistic	47920.95	48024.28	41136.69	41138.76	18926.82	18975.18	18671.02	18638.48
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: p-values are in parentisis
* significant at 0.05 level of significance

Table 5.7. New Single and Multi-plant Firms (1992-2000): Poisson model

when talking about the single-plant sample. On the contrary, the R&D and the human capital variables have always a better performance in the multi-plant case. Additionally, the local market is only relevant in the multi-plant sample. As before, the increase of the log-likelihood sustains the hypothesis of inclusion of dummies by NUTS3. Finally, we performed a Pearson test to evaluate the goodness of fit, which evidenced overdispersion and justified the estimation of a negative binomial model.

In tables 5.8 and 5.9 we present main estimation results for both single-plants and multi-plants. As before, we ran a simple negative binomial model with and without specific-effects by municipality. We also consider dummies by regions NUTS3 and both local and regional market influence.

	NEGATIVE BINOMIAL MODEL											
	With dummy by year*CAE		With dummies by year*CAE and NUTS3		With random effects by municipality and dummy by year*CAE		With random effects by municipality and dummies by year*CAE and NUTS3		With fixed effects by municipality and dummy by year*CAE		With fixed effects by municipality and dummies by year*CAE and NUTS3	
Variables	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)
Land costs	-0.659*	-0.614*	-1.041*	-0.997*	-0.501*	-0.500*	-0.489*	-0.492*	-0.650*	-0.660*	-0.462*	-0.464*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.008)	(0.008)
Labor costs	-0.742*	-0.689*	-0.715*	-0.722*	-0.957*	-0.945*	-0.957*	-0.952*	-0.929*	-0.917*	-0.940*	-0.936*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Human capital	-1.286*	-1.255*	-0.191	-0.444*	2.072*	2.238*	0.453	0.503	2.749*	3.085*	0.177	0.250
	(0.000)	(0.000)	(0.238)	(0.019)	(0.000)	(0.000)	(0.184)	(0.150)	(0.000)	(0.000)	(0.632)	(0.505)
Capital costs	0.004	0.004	0.022	0.023	-0.028	-0.022	-0.037	-0.032	-0.042*	-0.031	-0.044*	-0.039
	(0.779)	(0.766)	(0.135)	(0.109)	(0.167)	(0.276)	(0.075)	(0.121)	(0.051)	(0.144)	(0.044)	(0.074)
Regional market	0.301*	---	0.189	---	0.595*	---	0.433	---	0.746*	---	0.419	---
	(0.000)	---	(0.545)	---	(0.000)	---	(0.088)	---	(0.000)	---	(0.096)	---
Local market	---	0.144	---	0.197*	---	0.227*	---	-0.036	---	0.250*	---	-0.076
	---	(0.055)	---	(0.010)	---	(0.019)	---	(0.681)	---	(0.014)	---	(0.392)
Market accessibility	-0.151*	-0.174*	-0.212*	-0.209*	-0.122	-0.165*	-0.293*	-0.298*	-0.206*	-0.254*	-0.568*	-0.571*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.113)	(0.031)	(0.052)	(0.048)	(0.031)	(0.008)	(0.002)	(0.002)
Localization economies	0.550*	0.549*	0.551*	0.552*	0.599*	0.599*	0.574*	0.573*	0.583*	0.582*	0.558*	0.557*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urbanization economies	1.091*	1.046*	1.143*	1.093*	0.535*	0.525*	0.719*	0.719*	0.424*	0.428*	0.664*	0.669*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R&D	0.029*	0.026*	0.045*	0.043*	0.015	0.014	0.026*	0.026*	0.015	0.013	0.022*	0.023*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.095)	(0.144)	(0.007)	(0.007)	(0.120)	(0.174)	(0.026)	(0.022)
Constant	9.600*	11.05*	10.60*	11.56*	3.169*	7.06*	7.78*	11.40*	2.01	6.827*	9.38*	12.99*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.022)	(0.000	(0.001)	(0.000)	(0.183)	(0.000)	(0.000)	(0.000)
Number of obs.	14332	14332	14332	14332	14332	14332	14332	14332	14323	14323	14323	14323
Log likelihood	-18390	-18402.1	-17895.1	-17891.9	-17406.2	-17413.8	-17318.9	-17320.2	-16492.6	-16502.8	-16366.3	-16367.3
Pseudo R^2	0.2017	0.2011	0.2231	0.2233								
LR test	9290.14	9265.84	10279.98	10286.27								
	(0.000)	(0.000)	(0.000)	(0.000)								
Likelihood-ratio test of alpha=0	10000	10000	6396.39	6401.03								
	(0.000)	(0.000)	(0.000)	(0.000)								
Wald test					8444.84	8428.34	8615.28	8606.52	8346.90	8329.83	8563.91	8558.37
					(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: p-values are in parentisis
* significant at 0.05 level of significance

Table 5.8. New single-plant firms (1992-2000): Negative binomial model

As we can observe, the increase of the log-likelihood supports the addition of dummies by region and the inclusion of specific effects by municipality. The statistics of the Hausman test for the inclusion of random versus fixed effects [regressions (37) and (41)] equals 0.02, which leads us to consider random effects by municipality. We may then observe that single-plants are strongly influenced by agglomeration economies, land and labor costs and market accessibility. At the same time, market size and human capital have high elasticities but are only significant and with the expected sign if dummies for regions are not included. Furthermore, regional market have clearly a higher influence on location choice than local market. Finally, the R&D variable, while significant, has the lowest elasticity.

	NEGATIVE BINOMIAL MODEL											
	With dummy by year*CAE		With dummies by year*CAE and NUTS3		With random effects by municipality and dummies by year*CAE		With random effects by municipality and dummy by year*CAE and NUTS3		With fixed effects by municipality and dummy by year*CAE		With fixed effects by municipality and dummies by year*CAE and NUTS3	
Variables	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)
Land costs	-0.772*	-0.568*	-1.146*	-0.991*	-1.205*	-1.043*	-1.226*	-1.104*	-0.480	-0.487	-0.320	-0.368
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.249)	(0.232)	(0.545)	(0.484)
Labor costs	-0.293*	-0.278*	-0.440*	-0.468*	-0.597*	-0.597*	-0.603*	-0.606*	-0.686*	-0.681*	-0.653*	-0.649*
	(0.028)	(0.036)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Human capital	0.830*	0.213	0.988*	0.227	1.085*	0.291*	0.736	0.065	-0.518	-0.436	-0.659	-0.677
	(0.000)	(0.480)	(0.001)	(0.532)	(0.030)	(0.609)	(0.206)	(0.918)	(0.632)	(0.681)	(0.516)	(0.503)
Capital costs	0.074*	0.078*	0.071*	0.072*	0.071	0.075	0.079	0.083*	0.049	0.054	0.053	0.062
	(0.010)	(0.006)	(0.019)	(0.016)	(0.092)	(0.074)	(0.058)	(0.043)	(0.347)	(0.294)	(0.323)	(0.240)
Regional market	0.367*	---	0.121	---	0.390	---	0.271	---	0.100	---	0.439	---
	(0.001)	---	(0.838)	---	(0.128)	---	(0.633)	---	(0.858)	---	(0.450)	---
Local market	---	0.628*	---	0.644*	---	0.783*	---	0.683*	---	0.483	---	0.321
	---	(0.000)	---	(0.000)	---	(0.002)	---	(0.007)	---	(0.111)	---	(0.266)
Market accessibility	-0.146*	-0.169*	-0.136	-0.134	-0.156	-0.184	-0.160	-0.170	0.683	0.678	-1.139	-1.154
	(0.004)	(0.001)	(0.089)	(0.093)	(0.216)	(0.144)	(0.429)	(0.393)	(0.123)	(0.115)	(0.087)	(0.079)
Localization economies	0.459*	0.467*	0.503*	0.507*	0.523*	0.523*	0.526*	0.526*	0.542*	0.539*	0.520*	0.519*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urbanization economies	0.990*	0.780*	1.193*	1.011*	1.453*	1.278*	1.465*	1.293*	1.368*	1.303*	1.557*	1.496*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R&D	0.053*	0.047*	0.073*	0.065*	0.007	0.004	0.021	0.019	-0.016	-0.018	-0.021	-0.022
	(0.000)	(0.001)	(0.000)	(0.000)	(0.719)	(0.842)	(0.305)	(0.372)	(0.491)	(0.434)	(0.377)	(0.355)
Constant	1.256	1.744	6.041	5.028*	7.104*	7.648*	8.561	8.552*	6.017	4.533	10.716	13.262
	(0.291)	(0.108)	(0.224)	(0.000)	(0.006)	(0.000)	(0.084)	(0.000)	(0.308)	(0.229)	(0.217)	(0.064)
Number of obs.	14332	14332	14332	14332	14332	14332	14332	14332	13674	13674	13674	13674
Log likelihood	-6224.49	-6219.82	-6026.789	-6017.92	-5907.96	-5903.73	-5880.27	-5876.46	-5381.55	-5380.19	-5357.97	-5357.61
Pseudo R^2	0.1680	0.1686	0.1944	0.1956								
LR test	2514.12	2523.47	2909.53	2927.27								
	(0.000)	(0.000)	(0.000)	(0.000)								
Likelihood-ratio test of alpha=0	324.45	339.29	156.00	153.94								
	(0.000)	(0.000)	(0.000)	(0.000)								
Wald test					1931.14	1933.12	2031.17	2044.03	1872.40	1852.39	1791.07	1790.89
					(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: p-values are in parentisis
* significant at 0.05 level of significance

Table 5.9. New multi-plant firms (1992-2000): Negative binomial model

When talking about the location decision of new multi-plants, we may observe that although main location determinants are still the agglomeration economies and both land and labor costs, there are some noteworthy differences. The first remarkable difference is the relevance of the local market variable, instead of the regional market, which may be deduced from both overall and individual significance tests. In fact, we estimate that everything else constant, a 1 percent increase in local market size leads to about 0.7 percent increase in the number of new plants, while the regional market variable is often non-significant. As before, our estimation results support the inclusion of dummies by region and the existence of specific effects by municipality. Also, the statistics of the Hausman test for the inclusion of random versus fixed effects [regression (50) and (54)] equals 0, which supports the hypothesis that the specific effects are not correlated with the explanatory variables. We may also remark that, when considering random effects by municipality [regressions (47) to (50)], the elasticities of plant births with respect to land costs, local market and urbanization economies are the highest ones in multi-plant sample, while for the single-plant sample, the highest elasticities are due to labor costs and agglomeration economies.

We may then conclude that, as we suspected, the location determinants affect unevenly single-plants and multi-plants. In fact, we observed that new multi-plants are particularly sensitive to urbanization economies, land costs and local market, while new single-plant firms are more responsive to labor costs and agglomeration economies. Other differences concern market accessibility, which is not significant for multi-plants' location decision, and the R&D variable, which is only significant if no specific effects were considered, and, in this case, with higher elasticities than in the single-plant sample.

5.6.3 High-Technology and Low-Technology Industrial Plants

Literature on R&D spillovers usually supports the strong propensity for the clustering of innovation-related activities (e.g. Jaffe *et al* [115], Audrestch and Feldman [16]) and the relevance of R&D spillovers for innovation activities, which might depend on firms' industrial sector or size (e.g. Anselin *et al* [9], Varga [189], Arundel and Geuna [14], among others).

In this section, we will look at the role of R&D activities for the decision to locate new manufacturing firms, according to firms' technological characteristics. More precisely, we aim at evaluate if the birth of a new business is influenced by the location and size of R&D activities. Additionally, we questioned if the importance of R&D activities for location choice is different according to firms' technological characteristics.

To our knowledge, few works have addressed this topic. Araúzo-Carod [10] evaluated the importance of agglomeration economies, cost and demand variables for the location choice of new manufacturing firms according to firms' industrial sector. He observed that, for the R&D intensive sector, industrial diversity is the main location determinant, while the traditional sectors are more influenced by commuting costs. Also, Barrios, Görg and Strobl [20] focused on the determinants of location choice for foreigner high-tech and low-tech firms. They concluded that high-tech firms are particularly influenced by urbanization economies and access to transport infrastructure, while low-tech firms are more influenced by localization economies and public policies. In our study, we have also looked for the relevance of technological variables, particularly, R&D activities, for the location choice. Woodward, Figueiredo and Guimarães [198] focused also on the relevance of a particular type of R&D - the University R&D expenditures in science and engineering - for the location choice of new high-tech manufacturing firms. They concluded that the R&D expenditures at universities exert a positive but modest influence on firms' location decisions. The authors also estimated the distance from university R&D in which economic spillovers can be detected.

In this section, we intend to evaluate the importance of traditional as well as technological determinants for firms' location choice but assuming that firms behave differently if they have different technological capabilities. For that purpose, we recur to the OECD classification of industrial's technological intensity [151] ([52]) and consider two data-sets: the *low and medium-low technological industries* and the *high and medium-high technological industries*. A brief characterization of new plant births by technological-industrial sector is next presented (table 5.10).

As we can observe, the *low and medium-low technological industries* account for about 93% of total new manufacturing plants between 1992 and 2000, while the *high and medium-high technological industries* only account for about 7% of total new manufacturing plants.

[52] The OECD's classification of manufacturing industries based on technology (OECD [150]) uses two indicators of technology intensity: i) R&D expenditures divided by value added; ii) R&D expenditures divided by production. Industries are classified according to its average intensity in both indicators, having also under consideration both temporal and country median stability.

ISIC-Rev. 3	Manufacturing Industry	New manufacturing plants (1992-2000) Total	%
	High-technology industries	**455**	**1.22%**
2423	Pharmaceuticals	31	0.08%
30	Office, accounting and computing machinery	3	0.01%
32	Radio, TV and communciations equipment	127	0.34%
33	Medical, precision and optical instruments	279	0.75%
353	Aircraft and spacecraft	15	0.04%
	Medium-high-technology industries	**2 318**	**6.23%**
24 excl. 2423	Chemicals excluding pharmaceuticals	372	1.00%
29	Machinery and equipment, n.e.c.	1 375	3.69%
31	Electrical machinery and apparatus, n.e.c.	381	1.02%
34	Motor vehicles, trailers and semi-trailers	166	0.45%
352 + 359	Railroad equipment and transport equipment, n.e.c.	24	0.06%
	Total high and medium-high technology industries	**2 773**	**7.45%**
	Medium-low-technology industries	**8 864**	**23.81%**
23	Coke, refined petroleum products and nuclear fuel	4	0.01%
25	Rubber and plastics products	516	1.39%
26	Other non-metallic mineral products	2 503	6.72%
27-28	Basic metals; fabricated metal products, except machinery and equipment	5 681	15.26%
351	Building and repairing of ships and boats	160	0.43%
	Low-technology industries	**25 585**	**68.74%**
15-16	Food products, beverages and tobacco	4 035	10.84%
17-19	Textile, wearing apparel and dressing and dyeing of fur; Tanning and dressing of leather; Luggage, handbags, saddlery, harness and footwear	11 902	31.98%
20-22	Wood and of products of wood and cork, except furniture; Straw and plaiting materials; Paper and paper products; Publishing, printing and reproduction of recorded media	5 847	15.71%
36	Furniture and manufacturing n.e.c.; recycling	3 801	10.21%
	Total low and medium-low technology industries	**34 449**	**92.55%**
15-37	**Total manufacturing**	**37 222**	**100.00%**

Source: DEEP - MTE (1991-2000), *Quadros do Pessoal*

Table 5.10. New manufacturing plants (1992-2000), by technological intensity

In order to evaluate the importance of geographical, sectorial and technological variables for location choice, we performed a conditional logit model by means of its equivalence with Poisson model, which is guaranteed by using a set of dummy variables for each combination of year and 2-digit CAE sector. Additionally, we estimated a CLM with a set of dummy variables for regions (NUTS3) in order to capture the influence of other non-observable variables. Results are presented in table 5.11.

As we can observe, the increase in the log-likelihoods support the inclusion of dummy variables by regions NUTS3 [regressions (57), (58) and (61), (62)]. We may also perceive some remarkable differences in the location determinants of low and medium-low technology (LMLT) plants and high and medium-high technology (HMHT) plants. In fact, the location choice of new LMLT plants is very sensitive to agglomeration economies,

	LOW AND MEDIUM-LOW TECHNOLOGY INDUSTRIES				HIGH AND MEDIUM-HIGH TECHNOLOGY INDUSTRIES			
	Poisson model				Poisson model			
	With dummy by year*CAE		With dummies by year*CAE and NUTS3		With dummy by year*CAE		With dummies by year*CAE and NUTS3	
Variables	(55)	(56)	(57)	(58)	(59)	(60)	(61)	(62)
Land costs	-0.610*	-0.623*	-1.179*	-1.180*	-0.419*	-0.197	-0.689*	-0.650*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.089)	(0.000)	(0.000)
Labor costs	-1.056*	-0.924*	-0.962*	-0.960*	0.0004	0.119	-0.036	-0.037
	(0.000)	(0.000)	(0.000)	(0.000)	(0.997)	(0.212)	(0.729)	(0.719)
Human capital	-2.465*	-1.688*	-0.871*	-0.859*	-0.528*	-0.127	0.559	0.413
	(0.000)	(0.000)	(0.000)	(0.000)	(0.026)	(0.668)	(0.091)	(0.267)
Capital costs	0.065*	0.068*	0.079*	0.079*	0.014	-0.006	-0.011	-0.013
	(0.000)	(0.000)	(0.000)	(0.000)	(0.632)	(0.846)	(0.745)	(0.704)
Regional market	0.428*	---	0.165	---	0.973*	---	-0.157	---
	(0.000)	---	(0.407)	---	(0.000)	---	(0.801)	---
Local market	---	-0.243*	---	-0.008*	---	0.294*	---	0.132
	---	(0.000)	---	(0.822)	---	(0.033)	---	(0.389)
Market accessibility	-0.132*	-0.153*	-0.213*	-0.214*	0.042	-0.045	-0.169*	-0.165*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.406)	(0.357)	(0.044)	(0.049)
Localization economies	0.766*	0.758*	0.769*	0.769*	0.286*	0.290*	0.233*	0.232*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urbanization economies	1.092*	1.114*	1.294*	1.296*	0.709*	0.490*	0.669*	0.623*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R&D	0.063*	0.064*	0.050*	0.050*	0.037*	0.026	0.087*	0.085*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.012)	(0.081)	(0.000)	(0.000)
Constant	12.397*	15.174*	14.222*	15.590*	-5.768*	-0.658	4.162	2.380
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.520)	(0.430)	(0.096)
Number of obs.	10440	10440	10440	10440	3753	3753	3753	3753
Log likelihood	-21502.51	-21551.58	-18933.62	-18933.94	-3282.40	-3319.16	-3089.03	-3088.67
Pseudo R^2	0.5201	0.5190	0.5775	0.5775	0.2644	0.2561	0.3077	0.3078
LR test	46613.01	46514.86	51750.79	51750.15	2359.29	2285.77	2746.04	2746.75
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pearson statistic	36807.3	37192.43	29686.54	29693.3	5386.3	5482.05	4777.48	4769.39
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: p-values are in parentisis
* significant at 0.05 level of significan*ce

Table 5.11. New low and high-technology plants (1992-2000): Poisson model

labor and land costs and market accessibility, while capital costs and market size loses relevance. When considering the new HMHT plants, its elasticities with respect to traditional location factors is much lower. We may also observe that new HMHT plants are not sensitive to labor costs. At the same time, they are more sensitive to R&D expenditures than new LMLT plants. However, the Pearson statistics for the goodness of fit suggests that data comprises overdispersion and, for this reason, we should estimate a negative binomial model.

Tables 5.12 and 5.13 show main estimation results for both low and medium-low technology (LMLT) plants and high and medium-high technology (HMHT) plants.

	NEGATIVE BINOMIAL MODEL											
	With dummy by year*CAE		With dummies by year*CAE and NUTS3		With random effects by municipality and dummy by year*CAE		With random effects by municipality and dummies by year*CAE and NUTS3		With fixed effects by municipality and dummy by year*CAE		With fixed effects by municipality and dummies by year*CAE and NUTS3	
Variables	(63)	(64)	(65)	(66)	(67)	(68)	(69)	(70)	(71)	(72)	(73)	(74)
Land costs	-0.739*	-0.672*	-1.090*	-1.020*	-0.553*	-0.542*	-0.581*	-0.583*	-0.664*	-0.666*	-0.550*	-0.557*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
Labor costs	-0.842*	-0.804*	-0.780*	-0.790*	-1.031*	-1.019*	-1.036*	-1.030*	-1.009*	-0.996*	-1.023*	-1.017*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Human capital	-0.981*	-1.145*	0.004	-0.389*	1.917*	1.956*	0.625	0.626	2.509*	2.717*	0.376	0.410
	(0.000)	(0.000)	(0.978)	(0.044)	(0.000)	(0.000)	(0.065)	(0.070)	(0.000)	(0.000)	(0.310)	(0.274)
Capital costs	0.019	0.020	0.037*	0.040*	-0.015	-0.011	-0.028	-0.023	-0.032	-0.024	-0.037	-0.031
	(0.201)	(0.183)	(0.013)	(0.007)	(0.449)	(0.581)	(0.171)	(0.263)	(0.137)	(0.275)	(0.091)	(0.149)
Regional market	0.259*	---	0.327	---	0.485*	---	0.457	---	0.649*	---	0.442	---
	(0.000)	---	(0.306)	---	(0.000)	---	(0.074)	---	(0.000)	---	(0.081)	---
Local market	---	0.249*	---	0.308*	---	0.254*	---	0.023	---	0.280*	---	-0.012
	---	(0.001)	---	(0.000)	---	(0.011)	---	(0.799)	---	(0.008)	---	(0.894)
Market accessibility	-0.193*	-0.213*	-0.218*	-0.213*	-0.082	-0.120	-0.227	-0.236	-0.118	-0.165	-0.469*	-0.479*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.300)	(0.126)	(0.132)	(0.117)	(0.249)	(0.107)	(0.011)	(0.009)
Localization economies	0.588*	0.590*	0.595*	0.597*	0.642*	0.641*	0.615*	0.614*	0.624*	0.623*	0.596*	0.596*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urbanization economies	1.132*	1.065*	1.185*	1.107*	0.616*	0.596*	0.787*	0.778*	0.493*	0.487*	0.728*	0.725*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R&D	0.033*	0.031*	0.047*	0.044*	0.009	0.007	0.018	0.018	0.007	0.005	0.013	0.014
	(0.000)	(0.000)	(0.000)	(0.000)	(0.336)	(0.469)	(0.060)	(0.068)	(0.447)	(0.589)	(0.169)	(0.169)
Constant	10.799*	11.746*	10.051*	11.806*	4.903*	7.885*	8.186*	11.832*	3.407*	7.453*	9.784*	13.432*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.030)	(0.000)	(0.000)	(0.000)
Number of obs.	10440	10440	10440	10440	10440	10440	10440	10440	10431	10431	10431	10431
Log likelihood	-16215.3	-16219.9	-15738.4	-15731.2	-15217.1	-15220.3	-15138.5	-15140.1	-14299.5	-14305.6	-14185.5	-14187.0
Pseudo R^2	0.1861	0.1858	0.2100	0.2104								
LR test	7413.52	7404.33	6390.46	8381.67								
	(0.000)		(0.000)									
Likelihood-ratio test of alpha=0	11000	11000	6390.46	6405.43								
	(0.000)	(0.000)	(0.000)	(0.000)								
Wald test					6756.61	6750.7	6889.30	6878.54	6576.96	6567.49	6791.38	6782.90
					(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: p-values are in parentisis
* significant at 0.05 level of significance

Table 5.12. New low and medium-low technology plants (1992-2000): Negative binomial model

As before, we performed several models, which performed quite well, as it can be settled from the overall significance tests. In both samples, the increase in the log-likelihoods supports the inclusion of both dummies by regions NUTS3 and specific effects by municipality. Additionally, in both samples, LMLT and HMHT, the inclusion of random rather than fixed effects by municipality is justified by the Hausman test, which equals to 0.62 [regressions (69) and (73)] and 0.39 [regressions (81) and (85)], respectively.

Focusing on the LMLT sample, we may observe that the most significant location factors are the traditional ones: agglomeration economies, land and labor costs. In fact, if we introduce random effects by municipality [regressions (67) to (70)], then we estimate that,

	NEGATIVE BINOMIAL MODEL											
	With dummy by year*CAE		With dummies by year*CAE and NUTS3		With random effects by municipality and dummy by year*CAE		With random effects by municipality and dummies by year*CAE and NUTS3		With fixed effects by municipality and dummy by year*CAE		With fixed effects by municipality and dummies by year*CAE and NUTS3	
Variables	(75)	(76)	(77)	(78)	(79)	(80)	(81)	(82)	(83)	(84)	(85)	(86)
Land costs	-0.505*	-0.312*	-0.698*	-0.651*	-0.391	-0.331	-0.514	-0.497	0.479	0.457	1.509	1.574
	(0.000)	(0.044)	(0.000)	(0.000)	(0.154)	(0.242)	(0.059)	(0.072)	(0.378)	(0.396)	(0.082)	(0.072)
Labor costs	0.018	0.079	-0.032	-0.035	0.055	0.072	0.082	0.081	0.056	0.053	0.040	0.039
	(0.877)	(0.508)	(0.786)	(0.767)	(0.657)	(0.563)	(0.509)	(0.514)	(0.669)	(0.682)	(0.757)	(0.764)
Human capital	-0.491	-0.413	0.618	0.418	-0.224	-0.045	0.447	0.344	-1.194	-1.093	-2.247	-2.175
	(0.102)	(0.302)	(0.128)	(0.371)	(0.694)	(0.945)	(0.522)	(0.644)	(0.356)	(0.405)	(0.125)	(0.140)
Capital costs	0.026	0.016	0.012	0.011	0.003	0.007	0.050	0.047	0.017	0.014	0.0154	0.012
	(0.480)	(0.667)	(0.766)	(0.786)	(0.960)	(0.896)	(0.329)	(0.349)	(0.795)	(0.836)	(0.818)	(0.859)
Regional market	0.864*	---	-0.075	---	0.639*	---	-0.239	---	-0.334	---	-0.245	---
	(0.000)	---	(0.919)	---	(0.023)	---	(0.718)	---	(0.580)	---	(0.709)	---
Local market	---	0.429*	---	0.165	---	0.151	---	0.097	---	-0.186	---	-0.191
	---	(0.022)	---	(0.386)	---	(0.519)	---	(0.676)	---	(0.423)	---	(0.419)
Market accessibility	0.011	-0.055	-0.185	-0.179	-0.047	-0.084	-0.226	-0.226	-0.002	0.082	-3.607	-3.535
	(0.863)	(0.385)	(0.071)	(0.081)	(0.737)	(0.552)	(0.295)	(0.295)	(0.997)	(0.873)	(0.359)	(0.382)
Localization economies	0.234*	0.240*	0.201*	0.200*	0.182*	0.181*	0.180*	0.180*	0.166*	0.168*	0.161*	0.162*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urbanization economies	0.825*	0.643*	0.684*	0.632*	0.809*	0.767*	0.698*	0.675*	0.319	0.352	0.430	0.460
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)	(0.004)	(0.007)	(0.450)	(0.406)	(0.315)	(0.283)
R&D	0.036*	0.023	0.084*	0.082*	0.056*	0.054*	0.069*	0.069*	0.045	0.046	0.040	0.042
	(0.052)	(0.205)	(0.000)	(0.000)	(0.014)	(0.020)	(0.002)	(0.002)	(0.084)	(0.075)	(0.133)	(0.117)
Constant	-4.799*	-0.359	3.224	2.030	-1.626	2.608	5.402	3.145	3.944	1.515	26.700	23.424
	(0.001)	(0.784)	(0.601)	(0.223)	(0.575)	(0.229)	(0.354)	(0.174)	(0.570)	(0.740)	---	---
Number of obs.	3753	3753	3753	3753	3753	3753	3753	3753	3485	3485	3485	3485
Log likelihood	-3131.03	-3147.62	-3023.13	-3022.75	-2955.17	-2957.47	-2933.15	-2933.12	-2560.80	-2560.65	-2546.10	-2545.86
Pseudo R^2	0.1588	0.1544	0.1878	0.1879								
LR test	1182.31	1149.12	1398.11	1398.87								
	(0.000)	(0.000)	(0.000)	(0.000)								
Likelihood-ratio test of alpha=0	302.74	343.06	131.79	131.84								
	(0.000)	(0.000)	(0.000)	(0.000)								
Wald test					1277.48	1263.52	1418.90	1419.29	1189.51	1192.11	---	---
					(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	---	---

Notes: p-values are in parentisis
* significant at 0.05 level of significance

Table 5.13. New high and medium-high technology plants: Negative binomial model (1992-2000)

everything else constant, a 1 percent increase in labor costs lead to about 1.03 percent increase in the number of new plants. However, if we consider the HMHT sample, than we may retain an opposite behavior: cost factors and demand variables lose relevance, while agglomeration economies gain importance. In fact, we observed that the most relevant location determinant for high-tech firms are the urbanization economies, which accords with existing literature.

We may also observe that in both samples, capital costs are not significant or do not have predicted sign. On the demand side, we may conclude that, for the LMLT sample, the market size influence is much clear when dummies for regions are not included, while market accessibility is only significant if no specific effects by municipality were included. Conversely, both the local market and the market accessibility are not significant for location decisions made by new high and medium-high technology plants.

Finally, we may observe that the elasticity of plant births with respect to R&D expenditures is higher in the HMHT sample than in the LMLT one. We may then conclude that, in their location decisions, high and medium-high technology plants are strongly influenced by urbanization economies and R&D spillovers, while new LMLT plants are more responsive to agglomeration economies and cost factors.

5.7 Concluding remarks

Using micro-level data on manufacturing plants, this chapter examines the importance of geographical, sectorial and technological characteristics for firms' birth in Portugal between 1992 and 2000, according to firms' technological intensity and number of plants. Our main conclusions are summarized in table 5.14.

Our results confirm the relevance of agglomeration economies for firms' location choice, which accords with the existing literature. In fact, either when considering the entire manufacturing sector or when allowing for a division according to the number of plants or firms' technological intensity, the most important location determinants are the agglomeration economies. Additionally, urbanization economies seems to have a particular relevance for the location decision of new multi-plant firms and high-tech firms.

Estimation results also evidence that, with the exception of the high-tech sample, firms' location choice is influenced by labor and land costs. On the contrary, the hypothesis concerning the negative influence of capital costs on location choice is not confirmed in our study, which might be justified by the absence of significant differences in the cost of capital across Portuguese municipalities.

Hypotheses	Total new plants*		New single-plants*		New multi-plants*		New low-tech plants*		New high-tech plants*	
	Without NUTS3 dummies	With NUTS3 dummies	Without NUTS3 dummies	With NUTS3 dummies	Without NUTS3 dummies	With NUTS3 dummies	Without NUTS3 dummies	With NUTS3 dummies	Without NUTS3 dummies	With NUTS3 dummies
High land costs negatively influences new investments	✓	✓	✓	✓	✓	✓	✓	✓	×	×
High labor costs negatively influences new investments	✓	✓	✓	✓	✓	✓	✓	✓	×	×
High human capital positively influences new investments	✓	×	✓	×	✓	×	✓	×	×	×
High capital costs negatively influences new investments	×	×	×	×	×	×	×	×	×	×
High regional market size positively influences new investments	✓	✓	✓	×	×	×	✓	×	✓	×
High local market size positively influences new investments	✓	×	✓	×	✓	✓	✓	×	×	×
High distance to Porto or Lisbon negatively influences new investments	×	✓	×	✓	×	×	×	×	×	×
High localization economies positively influences new investments	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
High urbanization economies positively influences new investments	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
High R&D expenditures positively influences new investments	×	✓	×	✓	×	×	×	×	✓	✓

* Negative binomial model with random effects by municipality

Table 5.14. Location determinants of new manufacturing plants: Hypotheses

Our research also evidences that, in spite of an irregular behavior, the regional market is much more significant than local market for firms location choice, except when considering the location decision made by new multi-plant firms. Also, the accessibility to the main important cities in Portugal is only relevant for the location choices made by new single-plant firms. Finally, we have also observed that the human capital stock has an uneven behavior, which might be explained by the aggregate nature of the indicator.

In what concerns the technological variable, we might conclude that the elasticity of plant births with respect to the R&D expenditures was quite small, while it becomes higher when taking under consideration the high-tech sample. That is, in their location decisions, firms take into account R&D activities, which evidences the presence of R&D spillovers.

The study of location choice may proceed with some improvements in our research. An appealing research topic is to focus on the human capital variable and try to evaluate the influence of different types of human capital on firms' location choice. Another topic is to extend our research to the problem of firms' relocations: what determines firms' relocation decisions Additionally, we could extend our research to assess the size of knowledge spillovers. Finally, we aim at evaluate the influence of firms' geographical and technological distance on R&D cooperation.

5.8 Appendix: Firms' location determinants - Empirical studies

Author(s)	Dependent variable	Time Period	Spatial Unit	Economic activities	Methodological approach	Main explanatory variables	
Carlton (1983)	New firms in USA	1967-71	Standard Metropolitan Statistical Areas (SMAS) (USA)	SIC - 3079 (Fabricated Plastic Products), 3662 (Communication Transmitting Equipment), 3679 (Electronic Components)	Logit model	Localization economies	Man-hours in production
						Labor variables	Average wage
							Number of engineers
							Average unemployment rate
						Government policy	Corporate and income taxes
							Property tax
						Infrastructure	Electricity price
							Natural gas price
Bartik (1985)	New domestic firms in USA	1972-78	States (USA)	Manufacturing	Conditional logit model	Labor variables	Unionization
							Wage rate
							Education level of population
						Agglomeration economies	Existing manufacturing activity
						Land costs	Population density
						Geographic variables	Land area
						Government policy	Corporate tax
							Property tax
						Infrastructure	Energy prices
							Road density
							Construction costs
Hansen (1987)	New and re-located firms in S. Paulo (Brazil)	1977-79	Cities in S. Paulo State (Brazil)	Manufacturing	Nested multinomial logit	Localization economies	Employees in each own manufacturing sector
						Urbanization economies	Employees with 10 or more years of education
						Labor variables	Wage rate
						Land costs	Price of industrial land
						Accessibility	Road time distance to the city of S. Paulo
Schmenner, Huber and Cook (1987)	New firms in USA	1970-80	States (USA)	Manufacturing	Two-stages logit model	Input costs	Unionization
							Wage rates
							Education enrollments per production worker
							Building costs
							Energy costs
						Government policy	Property taxes revenues per personal income
							State and local spending per personal income
						Geographic variables	Mean January temperature
						Demographic variables	Population density

Author(s)	Dependent variable	Time Period	Spatial Unit	Economic activities	Methodological approach	Main explanatory variables	
Coughlin, Terza and Arrondee (1991)	Foreign firms (new and others) in USA	1981-83	States (USA)	Manufacturing	Conditional logit model	Agglomeration economies	Manufacturing employment per square mile
						Labor variables	Average wage in manufacturing
							Unemployment rate
							Unionization
						Land costs	Land area
						Market variables	Per capita income
						Government policy	Taxes per capita
							State effort to attract FDI
						Infrastructure	Highway road density
							Railroad density
							Airport density
Woodward (1992)	New foreign (Japanese) firms in USA	1980-89	Counties and States (USA)	Manufacturing	Conditional logit model (with small sample of alternatves)		
						Market size	Gravity adjusted personal income
						Labor variables	Unionization
							Unemployment benefits
							Productivity
							Wage rate
							Poverty level
							Unemployment rate
							Education level
						Government policy	Corporate tax
							Property tax
							Domestic unitary tax
							Worldwide unitary tax
							Home country support office
							Population density
							State effort
						Geographic variables	Land area
							Climate
						Agglomeration economies	Manufacturing establishments
						Infrastructure	Interstate connection

Author(s)	Dependent variable	Time Period	Spatial Unit	Economic activities	Methodological approach	Main explanatory variables	
Friedman, Gerlowski and Silberman (1992)	New foreign firms in USA	1977-88	States (USA)	Manufacturing	Conditional logit model		FDI origins
						Access to markets	Gravity adjusted personal income
							Access to a container port
						Labor variables	Unionization
							Productivity
							Manufacturing average wage
							Unemployment rate
						Government policy	Corporate tax
							Local taxes
							State effort
							Environmental regulation
						Geographic variables	Land area
Mani, Pargal and Huq (1997)	New firms in India	1994	States (India)	Manufacturing	Conditional logit model	Land costs	Population density
						Labor cost	Manufacturing wage
					(plus regional dummies)	Labor force quality	Man-days lost due to disputes
						Energy cost	Electricity cost
						Infrastructure	Proportion of electricity demand (power sh
						Agglomeration effects	Total manufacturing firms' output
						Environmental regulation	Share of environment spending in total exp
							Environmental cases per number medium+
						Other attractive factors	Per capita income
Shaver (1998)	Foreign firms/ domestic firms in USA	1982-87	States (USA)	Manufacturing	OLS Binomial logistic model	Agglomeration economies	Gross state product
							Per capita income
						Labor variables	Unionization
							Unemployment
						Government policy	Corporate tax
							Domestic unitary tax
							State effort to attract FDI
Wei, Liu, Parker and Vaidya (1999)	FDI inflow (pledged and realized) in China	1985-95	27 provinces (China)	All	OLS and Errors Components model for panel data		
						International trade	Export+import
						Labor variables	Average wage rate adjusted by productivity
						Technological variables	R&D employment
						Market size	GDP growth rate
						Infrastructure	Post and telecommunication services outpu
						Agglomeration economies	Population density

Author(s)	Dependent variable	Time Period	Spatial Unit	Economic activities	Methodological approach	Main explanatory variables	
Kittiprapas and McCann (1999)	Firms (electronic industry) in Thailand	1991	2 (4) regions (Thailand)	Electronics	Multinomial logit model	Market variables	Share of domestic sales in total sales
						Entrepreneurial culture	Share of local proprietors
							Number of workers per establishment
						Labor variables	Skills level of employees
							Regional wage rate
Head, Ries and Svenson (1999)	New foreign firms (Japanese) in USA	1980-1992	States (USA)	Manufacturing	Conditional logit model	Market size	State income
							Adjacent state income
						Labor variables	Manufacturing wage
							Unionization rate
							Unemployment rate
						Government policy	Corporation tax
							Labor subsidy
							Capital subsidy
							Unitary tax
							Home country support office
							Foreign trade zones
Wu (1999)	Number of foreign firms in Guanzhou (China)	1981-91	Metropolitan area of Guanzhou (China)	All	Poisson model; Negative Binomial model		
						Labor variables	Population potentiality
						Strategic accessibility	Distance to the city center
							Dummy if the site is nearby a hotel
						Policy variable	Dummy if site is in the Economic/Technolog
Coughlin and Segev (2000)	Number of new foreign firms in USA	1989-1994	Counties (USA)	Manufacturing	Negative Binomial model	Market variables	Personal income per manufacturing employe
						Labor variables	Manufacturing average wage/average produc
							Percent of population with a high degree
							Unionization rate
							Share of manufacturing employment in total
							Percent of black population
							Unemployment rate
						Government policy	Per capita property taxes
							State and local taxes as percent of gross state
							Foreign office to promote FDI
						Infrastructure	Counties with interstate highway
						Agglomeration economies	Percent of urban population
							Population

Author(s)	Dependent variable	Time Period	Spatial Unit	Economic activities	Methodological approach	Main explanatory variables	
Cheng and Kwan (2000)	FDI (Stock) in China	1985-95	29 regions (China)		GMM model	Agglomeration economies	Lagged FDI stock
						Market size	Per capita income
						Labor variables	Wage rate
							Education level - Senior high
							Education level - Junior and primary high
						Government policy	State effort
						Infrastructure	Road density
							Railway density
						Geographic variables	Geographic location (costal area)
Guimarães, Figueiredo and Woodward (2000)	New foreign firms in Portugal	1985-92	275 municipalities (Portugal)	Manufacturing	Conditional logit model (with small sample of alternatives)	Agglomeration economies	Manufacturing employment per km^2
							% manufacting employment in the same 3-di
							Share of employment in foreign plants
							Share of employment in tertiary sector
						Labor variables	Index of manufacturing wage
							Proportion of labor force with elementary ed
							Proportion of labor force with secondary edu
						Land costs	Population density
						Accessibility	Distance to Porto and Lisbon
Wu (2000)	Foreign firms in Guanzhou (China)	1981-91	Metropolitan area of Guanzhou (China)	All	Logistic regression model	Macro-location	Distance to the city center
						Transport accessibility	Dummy if the site has access to a railway ter
							Dummy if the site has access to a river transp
							Distance to the nearest road
							Distance to the nearest highway
						Strategic accessibility	Distance to the nearest high-ranking hotel
							Dummy if the site is nearby Garden Hotel
							Dummy if the site is nearby Convention Cen
						Land use factors	Land area
							Built-up area as a percentage of total usable
							Industrial land as a percentage of total land a
						Labor variables	Population potentiality
						Policy variable	Dummy if site is in the Economic/Technolog
Figueiredo, Guimarães and Woodward (2002)	New domestic firms in Portugal	1995-1997	275 municipalities (Portugal)	Manufacturing	Conditional logit model	Localization economies	Share of manufacturing employment in same
						Urbanization economies	Total manufacturing employment per square
						Labor costs	Average manufacturing wage
						Land costs	Population density
						Major urban accessibility	Time distance to Porto and Lisbon
						Minor urban accessibility	Time distance to *distrito*
						Investor's home base	Dummy = 1 if *concelho* coincides with inve

Author(s)	Dependent variable	Time Period	Spatial Unit	Economic activities	Methodological approach	Main explanatory variables	
Araúzo-Carod and Manjón-Antolín (2004)	New firms (number) in Catalonia	1987-1996	Provinces (4), comarques (41) and municipalities (942)	Manufacturing	[Multinomial logial model] [Conditional Logit model] Poisson		
						Urbanization economies	Total workers/km2
						Urbanization diseconomies	(Total workers/km2)^2
						Market size	Population density
						Industrial diversity	Hirschmann-Herfindahl index
						Human capital	Population with medium and high educatio
						Localization economies	Workers in each industrial sector/km2
Guimarães, Figueiredo and Woodward (2004)	Number of new firms in USA	1989-97	3066 counties (USA)	Manufacturing	Poisson model	Labor costs	Wage and salary earnings per job
						Land costs	Population density
						Taxes	Per capita property taxes
						Market size	County personal income
						Localization economies	Density of manufacturing and service plants
						Urbanization economies	Number of plants per km2 in the same 2-dig
Head and Mayer (2004)	New foreign firms (Japanese) in Europe (BE, FR, GERM, IREL, ITAL, NETHERL, Spain, PORT and UK)	1984-95	57 regions (EU)	Manufacturing	Conditional logit model Nested logit model		
						Labor variables	Wage by employee
							Unemployment rate
						Government policy	Region Obj. 1
							Regional land area
							Social charges rate (non-wages labor costs)
							Corporate tax rate
						Geographic variables	Regional GDP
						Market variables	Index of market potential
						Agglomeration economies	Number of establishments in the 2-digit indu
							Japanese affiliates in the 3-digit industry reg
Hogernbirk and Narula (2004)	New foreign firms in Netherlands	1992-96 (1995-96)	Netherlands regions	All	Conditional logit model		
						Agglomeration economies	Agglomeration of foreign firms
							Agglomeration of domestic firms
						Market variables	Market size
						Labor variables	Population density
							Unemployment rate
						Government policy	Property taxes
						Infrastructure	Road density
							Land area

Author(s)	Dependent variable	Time Period	Spatial Unit	Economic activities	Methodological approach	Main explanatory variables	
Holl (2004)	Number of new and relocated firms in Portugal	1986-1997	Portuguese municipalities	Manufacturing	Poisson and negative binomial models with fixed effects	Market variables	Municipality population
							Index of potential population accessibility
							Motorway access
						Agglomeration economies	Lack of diversity (employment specializati
							Industry share in total manufaturing emplo
							Producer services share
						Labor variables	Index of manufacturing wage
							% of labour force with low qualifications
Araúzo-Carod (2005)	Number of new firms in Catalan (Spain)	1987-96	Municipalities (Catalan)	Manufacturing	Poisson [Poisson by industrial groups (OECD)] [Conditional logit model]	Urbanization economies	Jobs/km2
						Dis-urbanization disecon.	(Jobs/km2)2
						Economic activity	% jobs at the industrial sector
							% jobs at the services sector
						Industrial diversity	Index HHI of diversity of industrial jobs
						Human capital	% Population with university degree
						Accessibility	Distance to capital/nearest city
							Commuting (Km traveled daily by employ
						Labor market	Population density
Pusterla and Resmini (2005)	New foreign firms in Bulgaria, Hungary, Poland and Romania	1995-2001	37 NUTS II - Bulgaria, Hungary, Poland and Romania	Manufacturing	Nested logit model	Agglomeration economies	Hoover's concentration index: domestic fi
							Hoover's concentration index: foreign firm
						Labor conditions	Per capita wages
							Level of education
						Economic size	Share of manufacturing employment in tot
						Land costs	Population density
						Infrastructure	Infrastructure public road density
Barrios, Gorg and Strobl (2006)	New foreign firms in Ireland	1973-82 + 1983-98	28 Irish counties	Manufacturing	Nested logit model	Localization economies	Sector share of total employment in the co
						Urbanization economies	Sum of square sectoral employment share
						Transportation infrastructure	Distance to the nearest international airpor
						Agglomeration diseconomies	Population density
						Foreign share	Foreign employment/total employment
						Firms of own nationality	Number of foreign firms with the same nat
						Labor skills	Real wage rate for the manufacturing indu
Woodward, Figueiredo and Guimarães (2006)	Number of new high-technology firms	1997-2000	Counties (USA)	Manufacturing (high technology)	Dirichlet-Multinomial model	Labor costs	Wage and salary earning per job
						Land costs	Population density
						Taxes	Per capita property taxes
						Market size (weighted)	Total county personal income (gravity mea
						Localization economies	Density of manufacturing and service plan
						Urbanization economies	Number of plants per km2 in the same 2-d
						Qualified labor	% of high school graduates or higher
						Natural amenities	Index of physical characteristics
						Weighted University R&D	University related R&D expenditures in sc

Chapter 6

Concluding Remarks

Understanding the decision processes by which firms decide about its geographical location and R&D cooperation is the main purpose of this thesis. More precisely, we aim at clarify how firms competing in the product market and benefiting from know-how spillovers decide about its geographical location and about cooperation in R&D.

We adopted a twofold approach: first, and inspired on location choice models and R&D cooperation literature, we proceed through theoretical modelling to evaluate how competing firms decide about location and R&D cooperation; second, we developed an empirical evaluation about the importance of geographical, sectorial and technological determinants for firms' location choice using micro-level data for the Portuguese manufacturing start-ups. Our main research conclusions are the following ones:

- The relation between R&D output and firms' geographical distance under R&D cooperation or competition was our first concern. As cooperation in R&D allows firms to internalize its knowledge spillovers, then its R&D output will be larger if firms agglomerate. However, if firms compete in R&D, its R&D output will be larger if firms disperse, as a lower proportion of its results flow over the other firms. So, in order to promote firms' innovation, policy makers should have under consideration both cooperative agreements between firms and its clustered or dispersed location.

- Firms' location choice is strongly influenced by knowledge spillovers and cooperation in R&D. In fact, if firms cooperate in R&D, the best location choice for an entrant firm is agglomeration, for every shape of the R&D spillover. However, if firms run R&D independently, then the entrant firm will cluster only if the R&D spillover is convex in distance. These conclusions allow us to clarify the competition-cooperation environment that characterizes the industrial clusters.

- R&D cooperation agreements between competing firms might involve uncertainty with respect, for instance, the amount of know-how each firm discloses to its partner. We assumed that geographical proximity between firms augments the confidence between entrepreneurs and reduces uncertainty. Our results supports an inverse relationship between transport costs and agglomeration. In fact, we concluded that if transport costs are significantly high, firms will prefer to disperse between regions and overcome the absence of knowledge spillovers by cooperating in R&D. On the contrary, if transport costs are low, cooperating firms will agglomerate if uncertainty with respect to the disclosure of know-how is high, and disperse if uncertainty is low. So, proximity between firms is a crucial determinant for R&D cooperative agreements between firms, as it reduces uncertainty.

- Location choice theory usually claims that the optimal location depends on production costs, demand variables and agglomeration economies. Additionally, we have under consideration the influence of technological variables on firms' location choice. Similarly to other empirical studies, we concluded that, for the Portuguese case, the main determinants for firms' location choice are the agglomeration economies and both labor and land costs. In addition, we observed that R&D expenditures, while significant, has a minor role on the attractiveness of business investments but evidence the presence of R&D spillovers. At the same time, the human capital is rarely significant.

- Location determinants may affect differently firms with different technological intensities. When considering the high-tech sample, we notice that the cost variables lose importance, while the agglomeration economies and the R&D expenditures gain relevance. On the contrary, costs variables and agglomeration economies are the major determinants for the location choice of low-technological firms.

- Finally, we focus on firms' structure and investigate the determinants of multi-plant and single-plant firms location choice. We then observed that new multi-plant firms are particularly sensitive to urbanization economies, land costs and local market, while new single-plant firms are more responsive to labor costs and agglomeration economies.

- In sum, Portuguese manufacturing starting plants are mostly sensitive to agglomeration economies and cost factors, while technological variables seems to be more relevant in attracting high-technological plants. At the same time, the capital cost and market variables revealed to be non-significant in most cases, which might be explained by the small dimension of our geographical unit. Finally, a last reference to human capital, which is not decisive for the attractiveness of new businesses.

Research on firms' location and R&D cooperation is far from being concluded. We expect to improve our research in several directions. In what concerns spatial competition and R&D cooperation between firms, and applying for contracts theory, our next step is to introduce information asymmetry by assuming that the disclosure effort is non observable if firms disperse, while it becomes observable if firms agglomerate. Additionally, we could extend our framework by assuming that firms may choose its technological profile, instead of its geographical location, and afterwards compete or cooperate in R&D. Claiming for agent-based computational economics, another possibility is to extend our model to a n heterogenous firms framework, where firms make their decisions about technological (or geographical) location and cooperation repeatedly. Empirically, an appealing research topic is to evaluate de determinants of firms' relocation decisions. Another possibility is to evaluate the influence of firms' geographical and technological distance on R&D cooperative agreements between firms.

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