Attraction and Repulsion

Modelling interfirm interactions in geographical space

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To
Sasha, Vasya and Volodya

Foreword

This volume is the result of a research project carried out at the Marketing and Strategy Department at the Stockholm School of Economics (SSE).

This volume is submitted as a doctor's thesis at SSE. In keeping with the policies of SSE, the author has been entirely free to conduct and present his research in the manner of his choosing as an expression of his own ideas.

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I would also like to thank my fellow PhD students Assia, Bow, Claes, Elena, Elia, Emre, Zeynep and especially my roommate Sergey for all the discussions we had in corridors during these years. The seminars were a key part in my development as researcher and I would like to thank both the old Institute of International Business crowd (Udo, Peter, Patrick, Carl, Henrik, Stefan, Lars, Jesper, Lin, Ciara, Laurence, Anna and Christian) and the members of the Center for Media and Economic Psychology (Richard, Patric, Per, Erik, Claudia, Mattias and Emelia). I would also like to extend additional appreciation to Marie, Malin, Kerstin, Lena and Vanja for making the whole process as smooth as possible.

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And above all I am thankful to my wife Mira, who joined me in Stockholm at the very start of this journey and made all these years as jolly and terrific as they were.

Stockholm, November 14, 2012

Sergiy Protsiv

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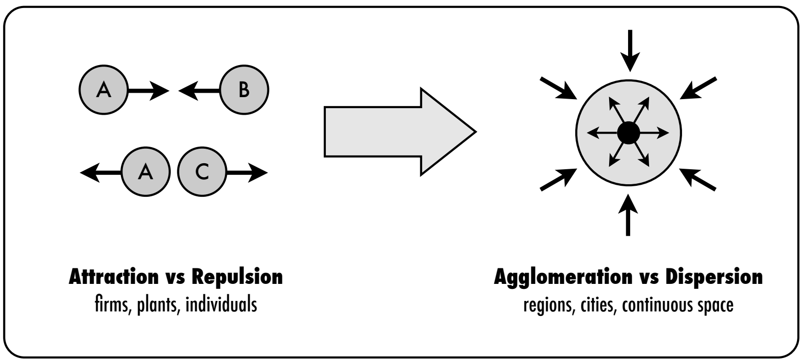
1. Introduction

Cities and forests are much alike. The complex interactions of people and firms mirror the intricate web of relationships between trees, animals and environment. Some plants attract each other due to symbiotic opportunities, while others repulse as they compete for sun and soil. Some ants settle as far away from their rivals as possible, while the more carnivorous species reside closer to the sources of their nutrition. There is a great deal of interaction going on in forests, and cities are no different.

A simple way to conceptualise these interactions is by identifying and defining the forces that bring actors together and those that drive them apart. The presence of a firm at a particular location can have a multitude of effects for other firms in close geographic proximity. It may attract them due to increased sales potential or the possibility of poaching skilled workers. But the firms could also repel each other due to competition or increased real estate prices.

The sum of these forces governs the movement of actors in geographical space. Should repulsive forces prevail, we would observe each firm selecting a location on a regular grid as far as possible from its neighbours. In the economic realm, however, the primary spatial phenomenon is the extreme agglomeration of human activity, as firms and people find it increasingly desirable to locate in denser areas. According to the United Nations, more than half of the world's population now lives in cities and urban areas are responsible for close to 80% of global GDP (United Nations, 2012). Still, the world's population is far from concentrated in a single city due to the forces that drive people away from these dense areas as they become more polluted and expensive.

Figure 1. Forces driving firm location



While conceptually this process is similar to the way that physical systems behave, the concept of movement is different in the context of people and firms. Rather than continuously moving towards the more attractive areas, firms often are established in locations that are relatively attractive for those in their sector, domain, or area of specialisation. Though there are many other factors that influence location decisions, such as founders' place of residence, firms rarely change their address.

In the economic system, the attractive forces manifest themselves by allowing firms that are located in more desirable and beneficial places to be more productive and innovative, thereby increasing their chances of survival. Conversely, the repulsive forces make the costs of locating in denser areas outweigh the benefits for some firms, resulting in them being forced to relocate or, in some cases, disappearing entirely. Thus, adjustments in this system transpire not only via firm movement, but also via firm closures and openings as described in Haig (1926).

While the attractive and repulsive forces are defined on the level of economic actors, such as firms, plants[1] or individuals, the aggregate location patterns that result from these interactions are analysed in terms of agglomeration or dispersion (see Figure 1).

Most empirical research in the field has been concerned with studying these aggregate outcomes on several spatial scales. The traditional approach is to compare several administrative or economic regions and examine their inequalities. Alternatively, one could study the hierarchy of cities of various sizes or explore the effects within single cities.

In this dissertation, I adopt a more direct approach to the analysis of firm location by studying the interactions on the level of plants and analysing these processes in continuous geographical space, without considering geopolitical borders or other arbitrarily imposed artefacts. I believe that this approach is beneficial since the effects are operationalised on the same level of analysis at which they are theoretically hypothesised, thereby avoiding unnecessary aggregation.

2. Density effects

Economic activity is extremely agglomerated, but why is this so? One potential explanation is the higher productivity of firms sited in denser areas. In fact, recent studies exploring these effects (e.g. Combes et al., 2010, and Study 1 of this dissertation) indicate the presence of positive effects of agglomeration on wages and productivity. It is remarkable that the elasticity of this effect appears to be consistently estimated at around 0.02 implying that doubling the density of economic activity in an area is associated with a 2% increase in productivity.

The effect appears to be fairly small and could imply the relative lack of importance of agglomeration economies (Duranton, 2011), though it could be difficult to discern the effects of doubling the density. To illus-

[1] The term "plant" is used in this thesis in the broad sense of an office, a factory, a retail store or, more generally, a place where business is conducted, goods are made, stored or processed, or services are rendered. The terms "plant" and "establishment" are used interchangeably within this thesis.

trate this, we use the 30th largest urban area in Sweden (the town of Östersund, which has a population of 44 327) as the basis for comparison. The increases in productivity in both the 20th largest city (Eskilstuna) and the 10th largest city (Jönköping) are marginal (see Table 1), though the differences become more substantial when looking at Malmö (third largest) and Göteborg (second largest), which have productivity increases of 7.7% and 14.7%, respectively.

Table 1. Estimated density effects on productivity

Urban area	*Population*[a]	*Maximum density*[b]	*Productivity increase*[c]
Stockholm	1 372 565	4 118	34.9%
Göteborg	549 839	1 861	14.7%
Malmö	280 415	1 085	7.7%
Jönköping	89 396	344	1.1%
Eskilstuna	64 679	265	0.4%
Östersund	44 327	223	N/A

[a] source: Statistiska Centralbyrån, 2010, [b] density computed using kernel smoothing with 5 km bandwidth, [c] relative to Östersund, computed using the elasticity of productivity to density of 2%

Finally, a firm in Stockholm, all other things being equal, is expected to be 35% more productive than one in Östersund. Thus, even though the elasticity of productivity with respect to density is fairly small in magnitude, extreme variations in the levels of density across space could result in substantial productivity benefits.

3. Attraction and repulsion

These extreme variations of density in space are more a norm than an exception when it comes to the distribution of human populations. Almost a quarter of Sweden's population lives in the country's three largest cities. This stands in stark contrast to many of the patterns observed in the natural world: while there are approximately five trees for each person in Sweden, the forests are much more evenly spread out and have a much lower density, as they cover an area that is 100 times larger than the country's built-up environments.

This suggests that attractive forces prevail in the economic realm, and these effects are seen on many levels, ranging from the concentration of jewellery stores on a single street to the concentration of much of Europe's population around the Rhine Valley. And yet we observe a hierarchy of cities of sizes big and small suggesting there are forces driving people away from extremely dense areas to more sparsely populated ones.

Understanding the whole system that results from these forces is crucial for understanding the location patterns that impact economic activity. This section surveys and reviews the theoretical explanations for attraction and repulsion.

Attractive forces

The classical source discussing agglomeration mechanisms is Marshall (1890/1920), who more than a century ago delineated several ways that firms could benefit from locating close to other firms:

- Local availability of qualified specialised labour — employers are more willing to locate in the areas where there are many workers that possess the necessary skills for their sector, and the workers themselves are relocating to such areas, as this is where they are more likely to find a suitable position;

- Knowledge is "in the air" — skills and knowledge are transferred among local workers as new ideas quickly spread and are continuously enhanced by others, thus engendering innovation and new ideas;

- Common use and sharing of expensive machinery — firms benefit from the common exploitation of specific facilities that would be too expensive to build and/or too inefficient if operated by a single firm.

These forces typically have been categorised and discussed in the recent literature as labour market pooling, knowledge spillovers and input sharing, respectively, and have been a source of continual empirical inquiry (see Rosenthal & Strange, 2004 for a review). There are positive findings for all of these mechanisms, with the most consistent ones being associated with labour-related factors. On the other hand, the topic that has garnered the most interest in recent research has been knowledge spillovers. However, this phenomenon has been the most difficult of the three to detect and measure, and thus the methods used to analyse knowledge spillovers have varied greatly, with metrics ranging from patent data (Jaffe et al., 1993) to new product introductions (Audretsch & Feldman, 1996) and the use of new technologies (Jofre-Monseny et al., 2011). Collectively, these forces are known as localisation externalities, since they take place in the areas where an industry is localised.

A contrasting point of view is developed in the works of Jacobs (1969), who emphasises the role of cities as the primary drivers of economic development. In particular, it is suggested that the diversity of activity that exists in most cities sparks the creation of "new work" due to the mostly unplanned knowledge spillovers between firms and workers. The key driving force for innovation, then, is the availability of a large pool of various industries all contributing to the "melting pot" of knowledge creation.

Duranton & Puga (2001) suggested a way to reconcile these two theories, hypothesising that new industries are generated within large diverse cities and are later transferred to smaller, more specialised areas for efficiency reasons. Another study by the same authors found that companies tend to locate their headquarters in places where business employment is abundant, but that specialised manufacturing activities are often located in smaller cities that have developed reputations for having experience in a particular industrial niche (Duranton & Puga, 2005).

The benefits that accrue from urbanisation do not end with diversity, however, and the sheer density of economic activity in cities brings with it a score of positive externalities. Perhaps the most important of these is access to large markets, or market potential (Harris, 1954), since cities offer a large number of potential customers located in a compact area. Haig (1926) promoted the role of the city as a facilitator for additional social contacts and discussed the idea that urbanisation benefits various industries in different ways, so that eventually only those benefiting the most will locate in central locations. Finally, the scale of most cities means that their infrastructure has the potential to be used in a more efficient way (Fujita et al., 1999), and firms are more likely to be located in close proximity to universities and other public institutions (Quigley, 1998).

The key difference between urbanisation and localisation economies is whether they emanate from firms in the same industry or all firms in a particular area, regardless of what these firms produce. A concept that expands the industrial scope of localisation economies is *clusters*, "the geographic concentrations of interconnected companies and institutions in a particular field" (Porter, 1998). This definition was later expanded to specify that the actors in clusters are linked by "commonalities and complementarities" (Porter, 2000) and by "externalities of various types" (Porter, 2003). This concept emphasises the importance of sophisticated local demand for the continued development of new ideas in an industry and advocates local competition, arguing that fierce rivalry makes companies more competitive, as firms are under pressure to improve and innovate.

One of the interesting aspects of clusters is the relatedness of industries and sectors, as well as the connections of firms and public institutions like universities and standards-setting agencies. Porter defined related industries as "industries … that can share activities in the value chain across industries (for example, distribution channels, technology development), or transfer proprietary skills from one industry to another" (Porter, 1990). Relatedness among sectors is one of the aspects of clusters that has received the most research attention (Boschma et al., 2008; Frenken et al., 2007); this topic deserves future exploration, as it has become more apparent that industrial classification hierarchies do not capture the full complexity of interactions among sectors.

Repulsive forces

The disadvantages of agglomeration are often disregarded by many scholars concentrating on the positive side of proximity effects. But the presence of so many cities of varying sizes suggests that there are limits to agglomeration benefits, as well as an optimal distribution of city sizes. Some industries are extremely dispersed, and some even specifically choose locations that are far away from dense areas. The reason for this is that agglomeration also introduces a considerable number of diseconomies, reflected primarily in the rise of land prices, increased congestion and intensified competition.

Some factors are always in limited local supply, and the more firms there are which are trying to exploit these factors, the more scarce and expensive they become (Hanson, 2001). The diseconomies resulting from usage of these resources are commonly referred to as congestion.

The most obvious of these factors is the limited availability of land, and hence the increases in land rents that occur with rising density of economic activity. Von Thünen (1826) was among the first to analyse the effects of agglomeration on land markets and model the rents for agricultural land as a decreasing function of the distance to the city. The same laws are often also at work within cities themselves, where the price of land in central business districts is orders of magnitude higher than in the suburbs, leading to the rise of extremely land-use-efficient downtowns that are dominated by skyscrapers.

But there are other limiting factors at play, as well: clean air becomes scarcer when an increasing number of people and cars become concentrated in a small area, and transportation infrastructure also has physical limitations.

These congestion forces are directly opposite to urbanisation externalities, yet are similar in that they occur regardless of the kinds of firms that are located nearby. Land prices and levels of pollution are the same for everyone, and only the industries that are relatively less sensitive to these factors, or that experience overwhelmingly large benefits stemming from agglomeration, would find it reasonable to locate in city centres.

On the other hand, there are forces that work within industries and the chief among them is competition. In economic geography, the standard way of modelling competition is via the degree of product differentiation within an industry. The more the products in an industry are differentiated from one another, the less competition there is between firms in this industry. The ubiquitous Chamberlin (1933) model of monopolistic competition, formalised by Dixit & Stiglitz (1977), is based upon consumers' preference for variety and the larger this preference, the less competition the producers will face.

Relating these issues to geography, competition generally tends to become fiercer as firms become more proximate in space to one another, and as such, firms are inclined to locate closer to their clients than to their competitors. The less the products in an industry are differentiated, the more important the factor of local competition becomes. Thus, in order for agglomeration to occur, its benefits need to outweigh the increased local competition, which is easier to accomplish in more differentiated industries. As a result, the greater the degree of product differentiation that exists in a particular industry, the more likely the competing companies in this industry are to colocate.

Summary

Having explored the main forces that influence agglomeration, we can align them along two dimensions: the direction of the force and its industry scope (Table 2).

Table 2. The forces of agglomeration and dispersion

	Attraction	*Repulsion*
Own and related sectors	Labour market pooling Input sharing Intra-industry knowledge spillovers Sophisticated local demand	Local competition
All sectors	Access to large markets Inter-industry knowledge spillovers Common use of amenities	Land rent Congestion

The location of the firms in space is largely influenced by the interplay of these forces. Thus, any model aiming at explaining the location of firms needs to take these factors into account, either by incorporating them directly, or by clearly stating the necessary assumptions.

The main purpose of this dissertation is to explore the processes that drive firm location by analysing the forces influencing individual plants that are embedded in a continuous geographical space.

4. Methodological issues

To achieve this purpose I rely on several methodological advances and a very detailed dataset. The key characteristic of this dissertation is the attention devoted to the issues of geography and space, which has been relatively neglected in previous literature.

Handling geography

The forces of attraction and repulsion are defined on the level of economic actors. Thus, when it comes to the operationalisation of these forces, it is sensible to analyse them on the same level as interactions that are defined as occurring among individuals, plants and firms, rather than aggregating them to a regional scale[2].

This analytical approach requires not only controlling for plant and/or individual characteristics when building regional aggregates, but also using micro-geographic data in order to be able to define the effects that are dependent on the distance between actors. This way, we move away from the overly simplistic approach that defines all firms as being located in the centroid of their region and measures interfirm distances as those between the centroids of their respective regions.

The primary problem with using this method of measurement is not that the resulting figures are poor indicators of actual distance — in fact, to the contrary, they often are fairly good proxies for regions that are located far away from each other. The problems are associated with two other underlying assumptions: namely, that the regions are homogeneous within themselves and that there are no effects across borders between adjacent regions. Since much of the discussion in this dissertation is concerned with various agglomeration effects and since it is customary to define them using measures of density as opposed to size (Ciccone & Hall, 1996), we will use density measures to illustrate the issues with regionally aggregated data.

Given a partitioning of space in regions, the density within each of these zones is simply the number of firms contained in it divided by a region's total area. Thus, the density is the same within a region — an assumption that becomes less and less valid as regional sizes increase. The natural inclination would then be to use the smallest available regions in order to avoid this bias. However, the smaller regions are, the harder it is to justify the other assumption — that firms in neighbouring regions have no effect on firms in a given region. Thus, we have a contradiction, with region sizes needing to be carefully balanced to achieve the best results.

This issue could be handled by using the smallest available regions to satisfy the within-homogeneity assumption and devising a scheme for in-

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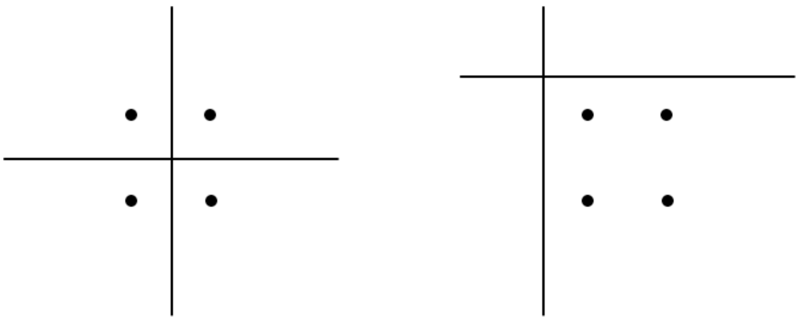
[2] Regional data has numerous other benefits, most notably that is typically easier to obtain, process and analyze, as well as to link different datasets.

corporating the neighbouring regions' values weighted by the distance to lessen the assumption that outside effects will have no impact. However, the validity of this approach is diminished by the fact that most regional borders are determined arbitrarily and often represent administrative or historical factors rather than economic ones.

Figure 2. The modifiable areal unit problem



Source: Quah & Simpson (2003)

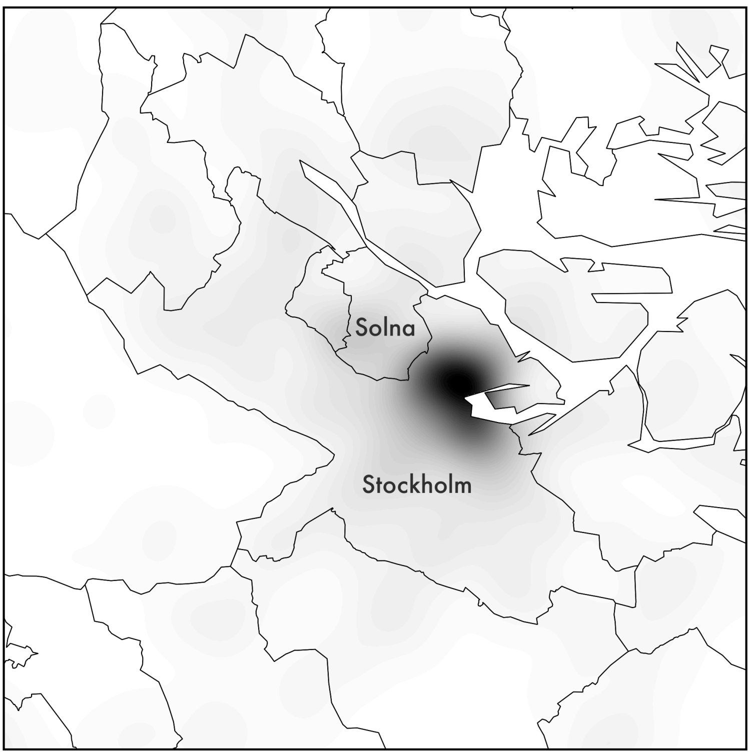
This issue is known as the Modifiable Areal Unit Problem (MAUP), and it can be illustrated with exactly the same locations of four firms on both diagrams in Figure 2 resulting in pure dispersion in the left case and complete concentration in the right one. The only change is the way the regional borders are drawn. Briant et al. (2010) show that the size, and to a lesser degree, the shape of regions play important roles in determining the estimated coefficients for industry concentration and agglomeration externalities, even though this effect is smaller than the variation induced by the specification of the model.

Figure 3. Municipality-level employment density in Stockholm region

The effect is empirically evident when the densities of municipalities in the Stockholm area are plotted (Figure 3). Smaller municipalities such as Solna score higher in terms of density than Stockholm proper due to the fact that they are very compact and only cover built-up areas. On the other hand, if we compute densities using plant-level data (Figure 4), it is evident not only that the density within Stockholm municipality is far from uniform, but also that the highest density areas are not in Solna, but rather in downtown Stockholm, to the southeast.

The preferred way to deal with MAUP and related issues is to abolish the use of regions altogether and instead use micro-geographic data in a continuous space. If the location of each firm is known, pairwise distances can be computed and all related measures can be made directly, thereby avoiding any potentially misleading assumptions. In fact, using point data could be seen as the extreme case of the small regions and weighted neighbours approach discussed above, whereby all regions contain exactly one firm and the distances between regions are the actual interpoint distances.

Figure 4. Plant-level employment density in Stockholm region



Other issues

Apart from the geographical issues, there are several other sources of difficulties that have been identified in the literature. Samples are often biased based on sector, most commonly using manufacturing only as in Duranton & Overman (2005), or on size, such as plants with more than five employees in Neffke et al. (2008).

The exclusion of services (as well as agriculture, publishing and many other sectors) is problematic because the rules applying to these domains should be similar to those operating in other sectors, although the magnitude of certain forces may vary. Other studies focus only on more "interesting" industries, which normally boils down to biotech, ICT and a few others. Though this bias can be justified if the analysis uses data that are not applicable to other industries (e.g. patenting intensity is heavily biased towards certain sectors), the fact that the majority of extant case studies (Cooke, 2008; Owen-Smith & Powell, 2004) focus on the biotech sector casts doubt on the universal applicability of the theories derived from these studies. Finally, there seems to be a near-universal belief that NACE and NAICS economic activity classification hierarchies are suitable for calculating the relatedness of industries (e.g. Frenken et al., 2007), whereas, it has been argued for the contrary by Porter (1998).

Plant size plays a less important role, as the bias may be less severe. However, Lafourcade & Mion (2007) incorporated it explicitly in their models and found significant differences resulting from variations in size. Among other findings, it was shown that large plants are much more concentrated than are their smaller counterparts.

As a result, since the methods employed vary in their sophistication and suitability, with even the best suffering from a range of shortcomings, research on the forces driving firm location, though extensive, has as yet proven inconclusive.

Micro-geographic approach

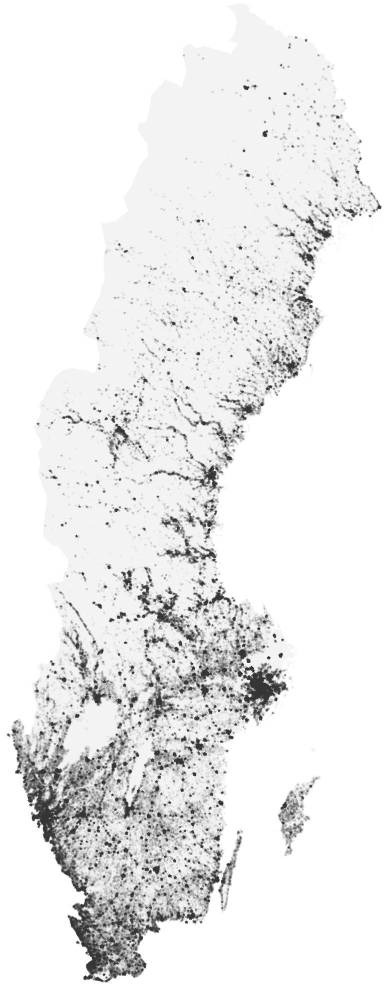
In this thesis, I address most of the issues outlined above. I use geocoded data, in which the vast majority of locations are determined with rooftop-level precision. This approach represents an improvement over previous micro-level studies, most of which use plant-level data but aggregate it geographically. Postal-code-level aggregation still often produces biased results, since their size varies rather dramatically depending on the density of population, though in some countries and regions, such as the United Kingdom (e.g. Duranton & Overman, 2005), the level of precision of postal codes approaches building-level accuracy. Furthermore, the locations used in the current study do not depend on any regional partitioning or other arbitrary factors, and thus MAUP is not an issue in calculating densities.

This dissertation relies chiefly on a rich dataset supplied by Bisnode AB that contains data on close to 1.6 million plants located in Sweden in 2008 (Figure 5). In addition to information on size and industry, the dataset supplies the visiting addresses, which were converted to geographical coordinates with a high degree of precision. Having knowledge of the locations of plants was key to the methodology used in the current study to estimate the density of economic activity in continuous space and to construct the measures for market and supplier potential, labour market access and knowledge spillovers.

In addition, the data employed span the entire breadth of the Swedish economy, including organisations in sectors such as services, agriculture and public administration. The agglomeration mechanisms could act differently depending on the sector and within sectors as well, depending on technology-intensity or special skill requirements. In addition, this requirement is manifested indirectly as the correct calculation of overall density, and indicators such as market potential require data drawn from the economy as a whole.

Finally, a key feature of the dataset employed is the presence of firms of all sizes, including those with no employees (i.e., sole proprietors, investment vehicles, etc.). These small firms are often excluded from official statistics for various reasons, but we use a commercial database that overcomes these constraints, allowing for analysis of the economy as a whole. Indeed, the employee-less firms constitute 76% of all companies in the dataset. And while in some cases, the inclusion of these firms may introduce additional biases, since some were established solely for tax or legal purposes, there are many types of businesses where this is a predominant form of operation. For example,more than 80% of establishments in creative industries lack employees.

Figure 5. Overview of the main dataset



We include all firms in our analysis and explicitly incorporate the influences of their sizes and sectors. Paired with extreme geographical detail, the analysis in this dissertation offers unprecedented scale and precision, which will allow it to contribute significantly to the literature.

5. Research questions

This dissertation deals with three sets of questions, each of which corresponds to a unique study.

Study 1

The first study concerns the effects of agglomeration on productivity and how these effects are different depending on industry and plant characteristics.

The first goal of this study is to estimate the magnitude of the effects of the raw density of economic activity on productivity. This is the basic question posed by the agglomeration economies literature, and the presence of agglomeration economies stemming from general density (i.e., regardless of the industry characteristics of neighbouring firms) would pave the way to exploring these effects in greater detail. Building on the detailed geographical data at our disposal, we attempt to estimate these effects using plant-level locations, thereby avoiding regional aggregation issues.

The forces driving agglomeration are not necessarily agnostic to the industries of other firms. It would be reasonable to expect that firms would be more attracted to firms that could become potential customers or suppliers, may have workers with similar skill sets, and could potentially result in knowledge spillovers. Thus, the second goal of Study 1 is to explore the importance of these different attractive forces in determining firm productivity using respective potentials measured on interfirm levels.

These mechanisms could play very different roles depending on the characteristics of the industry within which a firm is located. For example, higher-technology sectors could benefit more from technology spillovers, while less sophisticated industries will rely more on the presence of efficient transportation infrastructure. Exploring the differences between and among sectors could shed additional light on the specific spatial characteristics that firms should take into account when choosing locations, depending on the industry in which a particular firm operates.

Study 2

The second set of questions is chiefly concerned with the differences in location preferences between foreign-owned and domestic firms in Sweden. Foreign firms are hypothesised to be generally better managed, as only more productive firms venture abroad and of those, typically only the most productive undertake direct investment (Yeaple, 2009). Moreover, foreign firms tend to operate under fewer constraints in the sense that they are not encumbered by historical factors such as the owners' place of residence and therefore could be argued to be freer to choose amongst many possible locations (Görg & Strobl, 2003).

The goal of the second study is to analyse if the locations of foreign-owned firms are more influenced by agglomeration externalities compared to domestic companies. In particular, do foreign-owned firms locate in more urban areas and/or clusters, and do they have better acces to markets, suppliers and labour than their domestic counterparts.

The key merit of undertaking such an analysis for the research in this field is the use of detailed geographical data, as subnational studies of foreign direct investment are relatively rare and typically operate on a rather coarse geographical level.

Study 3

Finally, in the third study we switch from taking firm locations as given and ask whether it is possible to model the processes that result in these location patterns. In other words, instead of using location and derived indicators as predictors in the models and analysing the *effects of location*, we instead set location as the outcome variable and model the factors that *affect location*. To explore these effects, we first hypothesise whether firm location is driven primarily by the properties of the environment, such as presence of waterways or low terrain ruggedness.

However, since firms do not operate in a social vacuum and are engaged in interactions with their peers, we hypothesise that the presence of other firms would influence the probability of a given firm's location. In particular, we define a spatial interaction process based on the basic model of new economic geography (Fujita et al., 1999), where firms are attracted to each other due to increased market potential, but at the same time are repulsed due to increased property prices in denser areas. Thus, the principal research question in Study 3 is whether this simple economic geography model is consistent with reality and whether we can obtain location patterns that we observe in the real world.

6. Discussion

The studies that comprise this dissertation shed a significant amount of light on the processes that drive firm location and the impact of location on firm productivity. The most important study findings will be recounted in this section.

Magnitude of density effects

One of the basic questions in economic geography is whether the density of economic activity impacts the productivity of firms. The empirical research on this issue dates back to Shefer (1973), who found that the elasticity of productivity with respect to the size of an industry could be up to 0.27 or alternatively doubling the employment could lead to 27% increase in productivity. This effect appears to be extremely large, and later studies confirm this intuition. Sveikauskas (1975) and others estimated the effect of city size on productivity and generally found effects of around 5% to 7% in magnitude (Table 3).

More recently, Ciccone & Hall (1996) set the trend for studies of agglomeration effects on productivity in two ways. First, they advocated the use of data describing the density of economic activity rather than its absolute size, as density is argued to be a more accurate determinant of productivity. Second, they raised the issue of identification problems of agglomeration effects, as higher wages within a city could be a result of more productive workers living in denser areas and of inherent features of the area which make workers more productive. The authors proposed tackling this reverse causation using several variables that they argue are only related with productivity via their relationship with current density and not with factors causing endogeneity. Using different historical variables, such as mid-nineteenth-century population data and the presence of railroads, they found that the magnitude of the density effect is biased upward due to reverse causation, but only modestly so, as their estimated elasticities were also at around 6%, consistent with previous studies.

Table 3. Estimated density effects on productivity in previous studies

Study	*Dependent variable*	*Explanatory variable*	*Level of analysis*	*Estimated elasticity*
Shefer (1973)	Value Added	Population	SMSA[a] in US	14-27%
Sveikauskas (1975)	Value Added	Population	SMSA[a] in US	6%
Segal (1976)	Value Added	Population	SMSA[a] in US	8%
Moomaw (1981)	Value Added	Population	SMSA[a] in US	2.7%
Ciccone & Hall (1996)	Gross State Product	Density	Counties and states in US	6%
Combes et al. (2010)	Wages, TFP[b]	Density, Market Potential	Individuals aggr. to prov. in France	2-3.5%

[a] Standard Metropolitan Statistical Area, [b] Total Factor Productivity

A survey by Rosenthal & Strange (2004) reported that most of the studies estimated that doubling the size or density results in a 3% to 8% increase in productivity. However, more recent studies using detailed individual-level data and controlling for endogenous labour quantity and quality (Combes et al., 2010; Mion & Naticchioni, 2009) suggest that the magnitude of these estimates needs to be revised further, as their preferred estimate of the effect of density on wages is at 2%.

Using a dataset that is much more detailed geographically than previous studies (though not as detailed in terms of individual characteristics), we find an effect of similar magnitude. Depending on the spatial scale, we estimate that doubling employment density would lead to a 1.5% to 3% increase in wages. Aggregating the individual plant effects to regional averages, as has typically been done in the extant literature, suggests that significant biases are introduced via this procedure, and we believe that the micro-geographic indicators we use provide more precise results.

In general, it appears that the more detailed the data are and the more robust the estimation method is, the smaller the magnitude of the effect is. However, the fact that the most recent studies find effects of very similar sizes using different methodologies and data from different countries and sources suggests that we are approaching the goal of estimating the true effect of agglomeration on productivity.

Individual mechanisms

Among the relative impacts of the various mechanisms of agglomeration on productivity, perhaps the most extensively studied is the urbanisation versus localisation debate. The recent discourse on this topic is summarised in an excellent review by Beaudry & Schiffauerova (2009) that analyses 67 regression-based empirical articles estimating these effects. The key dependent variables in previous studies have been growth, productivity or innovation, which were explained using the various operationalisations of the respective externalities.

The results remain inconclusive, with about two-thirds of studies finding positive effects of localisation and a somewhat larger proportion finding positive effects of diversity. However, localisation effects were found to have negative effects on the variable of interest much more often than were urbanisation effects, which led the authors to suggest that specialisation of a region may also hinder economic growth.

The debate on the roles of different kinds of externalities has been extended by Glaeser et al. (1992), Henderson (2003) and Duranton & Puga (2001), who argued that diversity externalities are important in the early stages of industry development when ideas are absorbed from a large pool of diverse industries, while localisation externalities are important in more mature industries where increasing the efficiency of processes is more important. These hypotheses were confirmed by an extensive study on Swedish data conducted by Neffke et al. (2008).

Foreign firm location

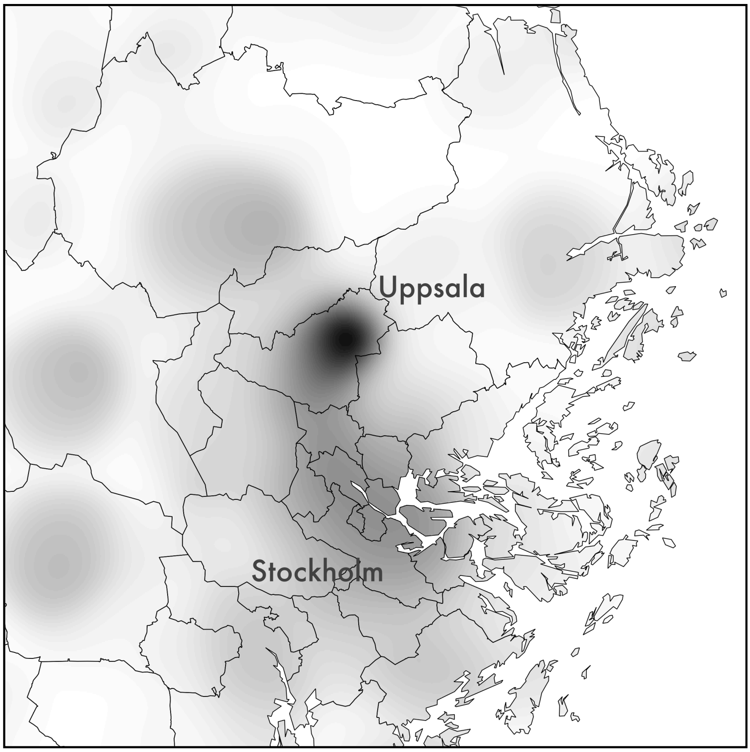
The location patterns of foreign direct investment have been at the forefront of research in various disciplines (Dunning, 1998; Beugelsdijk et al., 2010). While the relationship of these patterns with agglomeration has received some attention, most of studies have been conducted at the level of nations or sometimes large regions (Mudambi & Swift, 2012).

However, the detailed assessment of agglomeration effects requires the evaluation of the density of economic activity and various related indicators at a subnational level. In particular, the effects of market potential could be viewed in a narrower geographical sense than is often used in international business literature (i.e., local versus national).

One of the interesting exercises here is comparing foreign-owned firms to domestic ones. Figure 6 plots the relative density of foreign-owned firms compared to their domestic counterparts in Eastern Sweden. It is evident that foreign firms are more prevalent in denser urban areas such as Stockholm.

But what is particularly interesting is the pattern that connects Stockholm with Uppsala, which has the highest relative concentration of foreign firms in this area — double the rate seen in Stockholm. This suggests that it is not only raw density that is driving foreign firm location. Even though Uppsala is the fourth-largest city in Sweden, it still is nine times smaller than Stockholm.

Figure 6. Relative density of foreign-owned firms



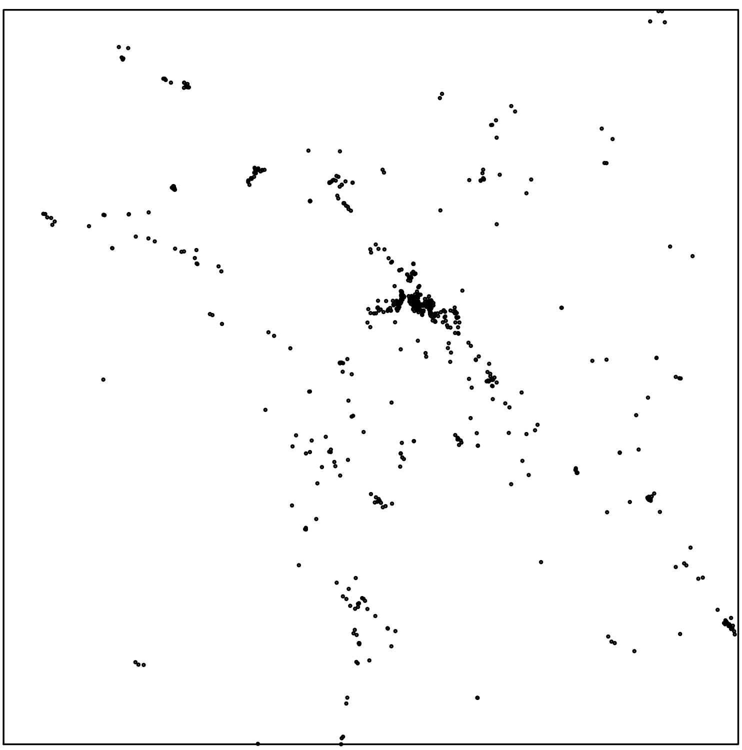
However, Uppsala is home to one of the oldest universities in the world and the city possesses very high levels of human capital — 4.5% of the population holds a postgraduate degree, compared to 1.7% in Stockholm. Uppsala itself and the corridor to Stockholm are also home to some of the biggest concentrations of ICT and biotech firms in Europe.

Extraordinarily high concentrations of foreign-owned firms in this highly attractive area (up to 8% of employment is within foreign-owned companies) suggests that these firms may indeed have made better location decisions than their domestic counterparts, whether due to better management or a relative lack of constraints.

Modelling location

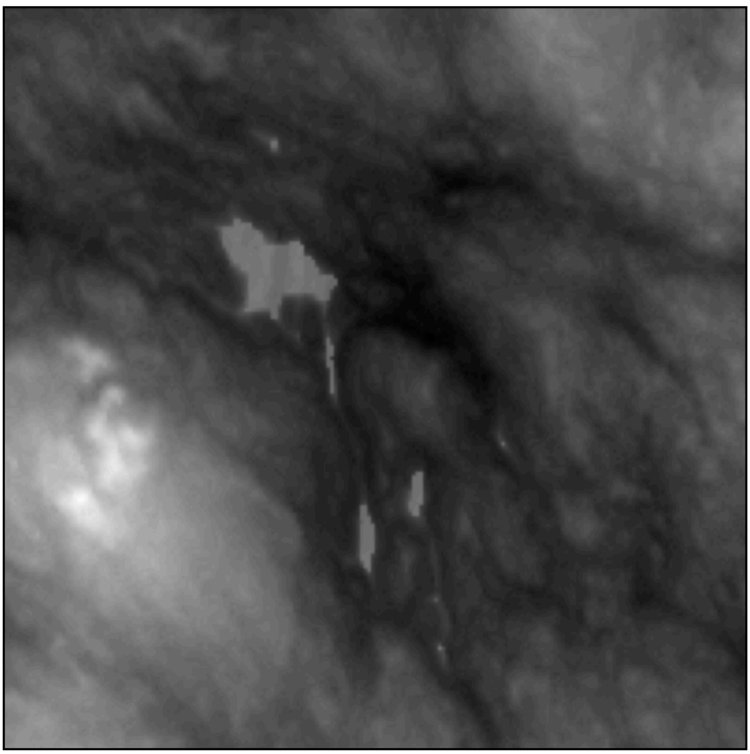
While the analysis of the location effects illuminates many reasons why a firm might prefer one location over another, it takes firm location as given. We believe that attaining a deeper understanding of the processes that lead to location choice requires reversing the sides of the equation and treating location as an outcome, not a predictor.

Figure 7. Pattern of manufacturing firms around Östersund



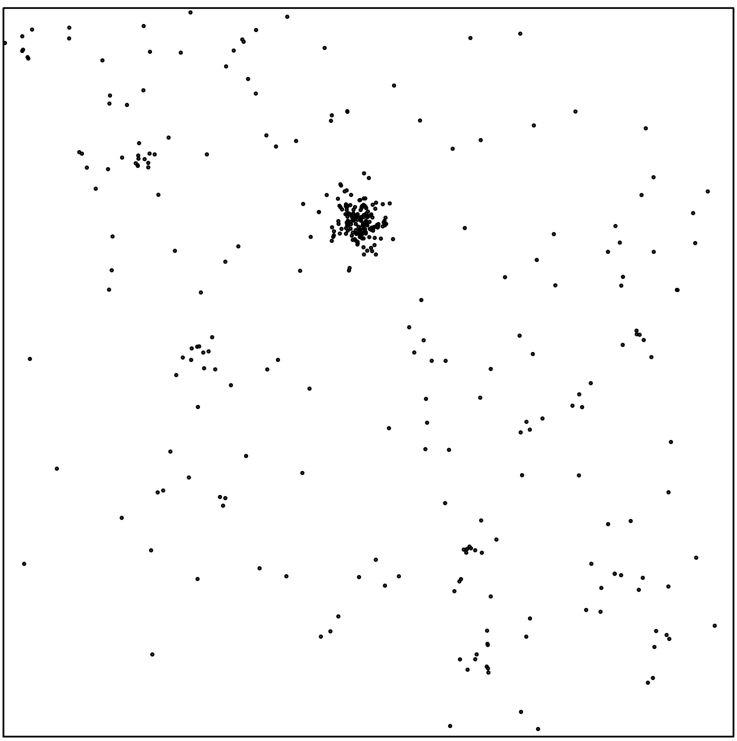
As firms are discrete events in the spatial sense, the most appropriate framework for analysis of their location is one that uses spatial point patterns. There have been a few studies exploring the concentration and co-location patterns using detailed micro-geographic data, but none of them attempted to analyse the 'spatial laws of motion' that result in observed patterns.

Figure 8. Predicted density of manufacturing firms around Östersund



One assumption could be that the probability of finding a firm at a given location depends solely on the features of a particular space. For example, firms may prefer to locate in close vicinity to rivers, lakes or natural harbours, while avoiding locales associated with severe weather or rugged terrain. The presence of such natural amenities was shown to significantly increase the attractiveness of locations for people and firms (Cheshire & Magrini, 2006, Rodrígues-Pose & Ketterer, 2012).

Figure 9. Simulated realisation of a spatial point process model



We analysed a subset of our complete dataset comprising 717 manufacturing firms in a 100x100 km region in a relatively isolated area around Östersund in Northern Sweden (Figure 7). Employing a host of physical covariates such as temperature, precipitation, elevation and distance to lakes, we predicted the density of firms in this area (Figure 8). Note that the central part of the figure has the highest density in an area where the actual city is located, as this place is flat, relatively warm, and located close to a lake.

However, the simulations based on this pattern have shown that while it has some predictive power, it is far from adequate in explaining real-world patterns, as it relies on the unrealistic assumption that the locations of firms are independent from one another.

When we define the interaction processes that take into account that the firms both attract each other due to increased market potential and repel each other due to increased housing prices, the results are much closer to reality. The pattern in Figure 9 is a simulation from the spatial point process model that includes both spatial inhomogeneity and inter-firm interactions.

The resulting pattern is remarkably similar to the observed one, and while the statistical properties of these estimators need to be explored with greater scrutiny, the first results from the application of spatial point processes in economic geography are rather promising.

7. Contributions

This dissertation makes significant contributions to the empirical research in economic geography and international business by analysing many of the hypothesised effects on an exceptionally detailed spatial scale. Many of the theoretical ideas regarding agglomeration externalities are further bolstered, as locations with local clusters, better market and supplier access, and thick labour markets show positive relationships with wages and the presence of foreign investment. These effects are also shown to be rather different depending on the properties of the industry as different spatial mechanisms are at play in finance, ICT and automotive.

On the other hand, the negative externalities from agglomeration, though not specifically tested for, exhibit themselves indirectly. The relationships between urban density and wages/foreign investment go from strongly positive to negative as soon as specific mechanisms of agglomeration are accounted for.

The implications of these findings for practitioners lie in the process of further confirming the potential benefits from choosing business locations carefully. Further, the results from Study 1 suggest that the individual externality types need to be treated with different significance depending on the industry the firm is in. Policymakers might find the results useful in that they support previous findings on a different spatial scale. However, it is also important to take note of the ever-diminishing magnitude of density effects as the methods become more sophisticated. Additionally, combined with the aforementioned negative externalities, it is important to find a balance between creating a flourishing environment and limiting clusters to a reasonable size to avoid over-agglomeration.

However, possibly the most important contributions of the dissertation are methodological. Advances in computational power coupled with increased data availability make the analysis of detailed geographical patterns possible. First, the proliferation of geocoding services makes the process of associating precise locations with addresses a fairly straightforward task. Second, the ability to conduct spatial queries in modern databases allows firms to be linked with environmental factors. Finally, the availability of specialised statistical software enables the estimation of the densities of millions of points in hundreds of industries on several spatial scales.

It is this density estimation capability that is of particular importance to the first two studies in this thesis. The level of geographical precision attained is unprecedented and avoids the pitfalls of region-based density measures. But the most important factors are the flexibility this process allows in analysing per-industry densities and particularly in recombining these densities to create spatial measures of market, supplier and labour force access. I believe that if data pertaining to exact locations is available, it is best to use the indicators much like the ones proposed in this thesis to measure the effects of agglomeration with a high level of accuracy.

Finally, the methodological potential of spatial point process modelling in economic geography is enormous, especially if some of the initial statistical and computational hurdles could be overcome. The questions of the spatial distribution of economic activity could be analysed on the microeconomic level without reverting to aggregations. The key advantage of the methodology is the ability to incorporate individual characteristics, peculiarities of various industries and features of the underlying space in the same model while keeping the variable of location as endogenous. The flexibility of this framework and the fact that it works in a realistic space could be the defining factors that bring the empirical research in economic geography and urban economics together.

The studies are also subject to several important limitations. First of all, the analysis is only done in Sweden and it is unclear how generalisable the findings would be in other contexts. However, it is reassuring that most of the results are in line with studies in other rather different countries, such as USA and France. Next, the dataset is purely cross-sectional limiting the ability to draw causal conclusions and control for some of the fixed effects. However, most of the agglomeration processes work over long periods of time, so short-term time series would not be particularly useful, while time series covering several decades at comparable level of geographical and industry precision could be hard, if at all possible, to obtain. Finally, some of the measures, such as wages and in some cases employee counts, are not very precise and to tackle the most important endogeneity issues, it would be preferable to obtain access to individual-level data to control for personal characteristics, precise wages and migration patterns. Combining this kind of data with detailed plant location patterns could provide a very insightful avenue for future inquiry into spatial economic issues.

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Short summaries of studies

Study 1

In this study, we analyse the impact of agglomeration economies on productivity. We build on a large body of theory on agglomeration economies, primarily drawing on the fields of urban economics and economic geography. The focus of the paper is, however, rather empirical and is built around the most precise estimation of the effect of urbanisation and localisation economies on the productivity of firms, and as such, we also briefly survey the key contributions to this area of study. Based on this, we define the economic model where the performance determinants are explicitly separated to firm-, industry- and location-related levels.

Since the primary focus of the paper is on location-related effects, we construct very detailed measures of agglomeration using kernel density estimates on different spatial scales. In addition to analysing the impact of the overall density of economic activity, we also computed the densities for every industry. In this way, we could recombine these densities using input-output tables to create the measures of market and supplier potential and use occupation statistics to estimate the thickness of local labour markets.

We use a subset of plants for which wage information was available (~170 000) to explore the effects of the various agglomeration mechanisms on productivity. The elasticity of the overall density of economic activity in relation to wages is estimated at 1.7 % after controlling for industry, climate and other nature-related effects. The magnitude of the effect is lower than most previous estimates, continuing the trend whereby the more detailed and precise the data are, the smaller the estimated elasticity.

When analysing the effects from separate agglomeration mechanisms, it was found that they are all positively related to the wage rates. However, the individual effects are harder to discern due to multicolinearity in predictor variables, though supplier potential appears to have the strongest effect, followed by knowledge spillovers. An interesting result is that as soon as a more specific agglomeration mechanism is added to the model, the effect of general density diminishes or becomes negative. This could suggest there are negative effects stemming from congestion in dense areas if these locations do not offer other benefits.

Finally, we explored the industry-specific effects from the individual mechanisms. Most of the effects turned out as expected, with higher technology manufacturing benefiting more from knowledge spillovers and knowledge-intensive services gaining from thick local labour markets (ICT) or high market potential (finance). Some other effects, such as negative externalities from labour market access for medium technology manufacturers, are harder to explain and require further exploration.

Study 2

The second study explores the subnational location patterns of foreign-owned firms and their dependence on various agglomeration externalities. We combine the literature from different streams of research on the location behaviour of firms in general and foreign-owned firms in particular. The theory is grounded in the international business field, and many of its implications can naturally be related to the literature on clusters and urbanisation/localisation economies. However, that would require going beyond the national level of aggregation prevalent in IB studies, and this has rarely been done before. Thus, this paper is an important empirical step in bridging the international business and economic geography literatures by analysing the behaviour of foreign-owned firms on the local level.

The methodology employed is similar to Study 1, though we construct additional measures for the density of foreign-owned firms. Also, since the outcomes in the models are the density itself and whether a firm is foreign or domestic, we did not need any firm-level performance indicators and could use the full sample of more than 1.3 million plants.

When comparing the foreign-owned firms to domestic ones, the results are consistent regardless of model specification and suggest that multinational firms choose more attractive locations with higher levels of all agglomeration externalities. There could be several explanations for this, including the notion that only a small subset of the best-managed firms venture abroad, or that foreign investment is much less constrained by factors that limit the freedom of domestic firms. Similarly to Study 1, the importance of overall density vanishes as other indicators are taken into account, reinforcing the idea of negative externalities stemming from congestion.

Study 3

The final study departs from taking locations as a given and focuses on modelling them explicitly. We propose expanding the toolbox of point pattern analysis methods used in economic research with spatial point processes. This methodology allows the specification of formal processes that result in spatial point patterns as outcomes.

We derive a formula for a spatial point process based on the basic new economic geography model, in which the attractiveness of a place is defined by the real wages a person is expected to earn there. We also incorporate the features of the space itself, such as temperature, elevation and proximity to water bodies in the model to allow testing against real-world patterns.

The dataset we explore is a rather small subset covering 717 manufacturing firms in a 100x100 km region around Östersund, a strategy that was employed in order to keep the computations manageable. We fit several basic models suggesting complete randomness of locations and their full dependence on spatial covariates such as climate. However, those processes are shown to be inadequate in producing patterns like the one which was observed, and we employ the economic geography-based interfirm interaction model. While the simple process itself produces reasonable results, it is the combination of interfirm interactions and spatial covariates that produces patterns remarkably similar to the observed one.