Knowledge externalities and firm heterogeneity:

Effects on high and low growth firms

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JEL: O18; O30; R10; R12; P48

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Effects on high and low growth firms

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Abstract

Knowledge externalities affect high and low growth firms differently. The paper develops two theoretical arguments. The *knowledge equilibrium argument* postulates that knowledge externalities weaken high growth firms for the benefit of low growth firms until performance differences vanish. The *knowledge competition argument* claims that high growth firms are in a better position to identify, attract, and integrate knowledge, thereby benefiting more from knowledge externalities than low growth firms. Based on 188,936 observations of 32,736 Swedish firms from 2004 to 2011, it is analyzed whether knowledge centers enable high growth firms to surge ahead or low growth firms to catch up.

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1 Introduction

The spatial organization of a firm's knowledge sourcing patterns and practices has been a topic of growing interest over the last 15 years. The spatial boundedness of knowledge spillovers is a result of the tacit dimension of knowledge, the socially embedded nature of network ties, and the relative immobility of skilled workers (Breschi and Lissoni 2001). This provides the foundation for knowledge-based agglomeration externalities that ultimately affect the innovativeness, productivity, and growth of firms. Location is thus "a key parameter that firms can use to increase their exposure to potential knowledge spillovers" (Alcácer and Chung 2007 p.760).

The aim of this paper is to investigate whether the effects of knowledge-based agglomeration externalities differ between high and low growth firms. It thus contributes to studies that stress the importance of firm heterogeneity for understanding the effects of positive and negative knowledge externalities in the form of knowledge spillover and leakage as well as labor pooling and poaching (Alcácer and Chung 2014; Rigby and Brown 2015; Alcácer and Delgado 2016; Grillitsch and Nilsson 2016; Knoben et al. 2016). The focus on high and low growth firms is of high relevance given that growth results from selection processes operating in a setting of relatively stable firm attributes, in particular firm routines, knowledge, and networks (Nelson and Winter 1982; Knudsen 2004; Grillitsch and Rekers 2016). This implies that all things equal high growth firms have by definition the most relevant and valuable knowledge, resources and networks to compete on the market, in short are "strong" firms. Conversely, low growth firms have less relevant and valuable knowledge, resources and networks, in short are "weak" firms.

So far, the literature has advanced theoretical arguments that lead to inconsistent hypotheses as regards the effects of knowledge externalities on strong and weak firms. On the one hand, the argument that firms with the strongest in-house knowledge endowments have the least to gain and the most to lose from co-location has found empirical support (Shaver and Flyer 2000; Kalnins and Chung 2004; Alcácer 2006; Grigoriou and Rothaermel 2016). This would imply that knowledge clusters enable weaker firms to 'catch up' and over time even out differences in competitive positions across collocated firms – i.e. achieving resource parity (Sirmon et al. 2010). On the other hand, such an inference is counterintuitive given that a firm's competitiveness depends to a large extent on its ability to generate, identify, attract and integrate new knowledge and skills (Cohen and Levinthal 1990; Kogut and Zander 1992; Grant 1996). From this perspective, strong firms should be better equipped than uncompetitive firms to benefit from knowledge externalities in terms of attracting and retaining qualified labor, collaborate with other strong organizations, or being able to absorb firm-external local knowledge.

In order to contribute to solving this paradox, this paper draws on three streams of literature: (i) the knowledge-based view of the firm, (ii) studies of knowledge spillovers and firm performance, and (iii) agglomeration theory within economic geography. The *knowledge-based view* of the firm holds that a firm's competitiveness largely depends on its ability to identify, attract, and integrate knowledge (Cohen and Levinthal 1990; Prahalad and Hamel 1990; Kogut and Zander 1992; Grant 1996). The mobilization of firm-internal and firm-external knowledge allows firms to learn and innovate, reap Schumpeterian rents and grow (Cohen and Levinthal 1990; Chesbrough 2003; Laursen and Salter 2006). The concept of *knowledge spillovers* is an extension of the knowledge-based view that has been widely drawn upon to explain the positive and negative effects of firm-external knowledge on firm performance. Notwithstanding recent qualifications, knowledge spillovers are often associated with positive effects on innovation, firm survival and growth (Jaffe et al. 1993; Audretsch and Feldman 1996b; Andersson et al. 2005; Acs et al. 2007). In contrast, an influential argument, advanced in particular in the management literature, is that the negative effects of industry clustering outweigh the positive effects for firms with leading in-house knowledge – inferring that such firms have little or no benefit from localized knowledge externalities stemming from other firms (Shaver and Flyer 2000; Alcácer 2006). Thirdly, within *economic geography*, the existence of and effects from local and global knowledge flows has long been of central concern (Bathelt et al. 2004; Storper and Venables 2004). This literature provides insights into why and how geographical and other forms of proximity to knowledge sources matters (Boschma 2005). Much emphasis has been placed on the importance of face-to-face interactions for the transfer of tacit knowledge, the social and institutional embeddedness of knowledge, as well as the importance of local labor markets (Gertler 2003; Malmberg and Maskell 2006; Breschi and Lissoni 2009; Belussi and Sedita 2010; Grillitsch and Nilsson 2015).

Based on these literatures, the paper advances a discussion along three dimensions. The first dimension captures the origin of knowledge-based agglomeration externalities where a distinction is made between local knowledge spillovers and local labor market dynamics. The second dimension refers to the directionality of the effects on firm-level performance, i.e. whether the externalities are positive or negative for a given firm. The third dimension takes up the debate on strong and weak firms and carves out two fundamental theoretical arguments which should hold for most firms given that other conditions are equal. On the one hand, the *knowledge equilibrium argument* predicts that negative knowledge externalities weaken strong firms for the benefit of weaker firms, thereby evening out differences between firms. On the other hand, the *knowledge competition argument* suggests that strong firms are in a better position to identify, attract and integrate new knowledge, thus being able to surge further ahead in knowledge-dense regions. These two competing arguments are tested in an empirical study drawing on a panel data set of 32,736 firms and 188,936 observations in Sweden over the period from 2004 to 2011.

2 Theoretical framework

2.1 Why geography matters

Knowledge-based effects of collocation can be boiled down to two distinct conceptual dimensions i) local knowledge spillovers and ii) local labor market dynamics. The *first* dimension captures local knowledge flows through informal channels and formalized networks. Firms in knowledge-dense regions benefit from greater knowledge and information diffusion in the form of local buzz (Bathelt et al. 2004; Storper and Venables 2004) – i.e. the informal and often unintentional flow of knowledge and information in such localities (similar to what Alfred Marshall (1920) described as knowledge 'in the air'). This has been discussed in terms of spatially bounded social embeddedness or industrial atmosphere (Tallman et al. 2004). Furthermore, collocation also facilitates formal collaboration between actors both in terms of a greater ability to identify and build linkages with relevant exchange partners, and in terms of easing the flow of knowledge between actors.

As regards the latter, it has long been recognized that knowledge diffusion and interactive learning is facilitated by different types of proximity capturing cognitive, cultural, institutional, social and geo-spatial characteristics (Amin and Cohendet 2004; Boschma 2005; Basile et al. 2012; Hansen 2014). These types of proximity are highly interrelated (Nilsson and Mattes 2015). Geographical proximity (collocation) is a proxy for and one of the determinants of cultural, institutional, and social proximity. This means that when actors are collocated there is a greater likelihood that they also share the same culture; hold similar norms, values, and follow the same regulations and legislation (institutional proximity); that they are more likely to share social networks; and hold similar fundamental cognitive frameworks. Furthermore, it is also argued that collocation facilitates the creation of social ties, norms and values, cognitive frameworks etc. as these often evolve with social and typically face-to-face interaction – such interaction is more likely to exist and to be intense when actors are collocated (Malmberg and Maskell 2006; Healy and Morgan 2012). This line of explanation emphasizes also the difficulty to share knowledge with a high tacit dimension across space (Lam 2000; Gertler 2003; Tallman et al. 2004; Belussi and Sedita 2010) as well as the deterrence effects from opportunistic behavior (Maskell 2001). Storper (1995) labeled these effects the untraded interdependencies within a region.

It should be stressed that while much has been written about the dynamics of local knowledge flows, knowledge diffuses of course not only in the local environment. Firms draw on a combination of local and non-local knowledge linkages in a dynamic process of knowledge creation. Knowledge-dense regions, however, potentially facilitate a firm's ability to build and maintain distanciated ties (Moodysson 2008; Belussi and Sedita 2010; Bathelt and Turi 2011; Morrison et al. 2013). A combination of local buzz and extra-regional pipelines is thus considered conducive to learning and innovation as pipelines provide an inflow of knowledge and information into the region whilst local knowledge flows diffuse such knowledge throughout the region (Bathelt 2007).

While much focus has been on the positive effects from local knowledge spillovers, there are also negative knowledge spillover externalities. Most notably this takes the form of knowledge leakage. For the same reason that firms in knowledge-dense regions are more exposed to the positive effects of knowledge spillovers, knowledge leakage is more likely in knowledge centers than in the knowledge periphery (Mariotti et al. 2010).

The *second* dimension of knowledge-based agglomeration externalities relates to local labor market dynamics and the labor sourcing behavior of firms. Based on the contention that knowledge and skills are embodied in individuals, local labor market dynamics go a long way in explaining the clustering of knowledge-intensive actors and activities (Boschma et al. 2014). Several studies have shown that highly skilled labor is not perfectly mobile (Almeida and Kogut 1999; Breschi and Lissoni 2009), implying that firms can more readily find skilled labor if located in regions with thick labor markets. Based on this, a number of studies link local labor flows to superior firm performance (Eriksson and Lindgren 2009; Eriksson 2011).

As in the case of local knowledge spillovers, a thick local labor market gives rise to both positive externalities in terms of greater availability of skilled labor (labor pooling) and negative externalities due to labor poaching, less investment in training, and rising factor costs for labor. Several studies find that because of the risk of labor poaching, firms in knowledge-dense regions invest less in employer-provided training (Brunello and Gambarotto 2007; Muehlemann and Wolter 2011). Similarly, Combes and Duranton (2006) argue that in settings with intense rivalry (like in knowledge-dense regions) the negative effects from labor poaching outweigh the benefits of labor pooling (cf. Alsleben 2005; Angeli et al. 2013). Table 1 summarizes the knowledge-based agglomeration externalities discussed above.

Table 1: Knowledge-based agglomeration externalities

Origin of externalities	Positive externalities	Negative externalities
Local knowledge spillovers	Local buzz Tacit knowledge transfer Localized collective learning Informal networks Trust-based knowledge sharing	Knowledge leakage
Local labor market dynamics	Labor pooling	Labor poaching Less incentives to invest in training

2.2 Why firm heterogeneity matters

A number of empirical studies have found that the effect of knowledge-based agglomeration externalities on firm performance is contingent on firm-level factors (Rigby and Brown 2015; Alcácer and Delgado 2016; Grillitsch and Nilsson 2016; Knoben et al. 2016). Contributing to this very recent literature, the research question of this paper is to what extent the relative importance of positive and negative knowledge externalities differs between high and low growth firms. The theoretical and empirical relevance of focusing on high and low growth firms is anchored in evolutionary theory, which argues that survival and growth results from market selection processes. A precondition for selection processes to work is that certain firm characteristics are relatively stable over time, notably firm routines, knowledge, and networks (Nelson and Winter 1982; Knudsen 2004; Grillitsch and Rekers 2016). This implies that, ceteris paribus, high growth firms have by definition the most relevant and valuable knowledge, resources and networks to compete on the market, and are thus referred to below also as "strong" firms. Conversely, low growth firms have less relevant and valuable knowledge, resources and networks, i.e. are "weak" firms.

The literature draws on two lines of thought that are particularly relevant for explaining firm-level contingencies, which are condensed in this paper to two key theoretical arguments. The *knowledge equilibrium argument* starts from the presumption presented above, that high growth firms tend to possess more relevant and valuable knowledge, resources, and social capital than low growth firms. Knowledge spillovers between high and low growth firms would then entail that strong firms can source mainly comparatively less-relevant and poorer quality knowledge from weak firms while, conversely, weak firms can source more relevant and valuable knowledge from strong firms (Shaver and Flyer 2000; Alcácer 2006; Alcácer and Chung 2007). This means that strong firms have more to lose and less to gain from local knowledge spillovers while the opposite is true for weak firms (Boschma and Frenken 2011):

> *"The 'poor' technology firm will be able to capture some of the 'good' technology firms' capabilities due to spillovers. The 'good' technology firm will be able to capture some of the 'poor' technology firms' capabilities due to spills-over."* (Shaver and Flyer 2000, p. 1177)

In a similar vein, high growth firms are the prime target for labor poaching as their employees tend to possess the most sophisticated knowledge, experience and personal linkages; which in turn enable firms to compete. At the same time, high growth firms have little benefit from recruiting labor that has been trained and has internalized routines and practices from comparatively weak firms. Taken together, the knowledge equilibrium argument is consistent with existing theory that suggests that, in munificent environments, it is significantly easier for a firm to increase the value and quality of its resources to a situation of competitive parity than to build competitive advantage (Barney 1991; Sirmon et al. 2010).

Consequently, knowledge-based agglomeration externalities should work to the benefit of weak firms and to the disadvantage of strong firms until the differences between weak and strong firms have vanished and "knowledge equilibrium" has been achieved. Accordingly, the following hypotheses can be phrased:

- Hypothesis 1: For high growth firms, the negative effects of knowledge-based agglomeration externalities outweigh the positive externalities.
- Hypothesis 2: For low growth firms, the positive effects of knowledge-based agglomeration externalities outweigh the negative ones.

The *knowledge equilibrium argument* is contrasted with a *knowledge competition argument*. Firm competitiveness (and ultimately their performance), it is commonly argued, depends to a large extent on a firm's ability to generate, identify, attract and integrate new knowledge and skills (Cohen and Levinthal 1990; Kogut and Zander 1992; Grant 1996); i.e. on their ability to reap knowledge-based and thus quasi-fixed Richardian rents (Peteraf 1993). This presumption finds wide support, especially for countries with high-factor costs where value is created through innovation; this is to say through the introduction of new products, improved processes, appealing marketing strategies, and new business or organizational models (Schumpeter 1934). Innovations are the result of interactive learning processes that mobilize firm-internal and firm-external knowledge (Cohen and Levinthal 1990; Chesbrough 2003; Laursen and Salter 2006) enabling firms to reap Schumpeterian rents and grow.

Following the *knowledge competition argument*, high growth firms are the main beneficiaries of local knowledge spillovers. Strong firms are more attractive collaboration partners precisely because they hold more valuable knowledge and resources (Ahuja 2000; Ter Wal and Boschma 2011). Furthermore, strong firms have a greater ability to absorb relevant external knowledge (Cohen and Levinthal 1990; Zahra and George 2002), possess complementary resources, organizational routines, market reach and distribution channels to turn knowledge into innovations and growth (Teece 1986), and to protect their intellectual property. Furthermore, because of so called asset mass efficiencies firms that already possess strong knowledge and other resources benefit more from adding increments of external knowledge (Dierickx and Cool 1989).

As regards local labor market dynamics, high growth firms have not only a greater demand for skilled labor but should also be more able to attract and retain qualified labor in terms of future wage development, promising career paths, higher job security and status (cf. Aldrich and Auster 1986; Williamson et al. 2002; Ndofor and Levitas 2004). In contrast, weak firms experience higher negative effects from local labor market dynamics because their most talented employees will be the first to move. The *knowledge competition argument* implies that strong firms can surge ahead in knowledge-dense regions as they are in a better position to identify, attract and integrate new knowledge and skills.

Following these arguments, two alternative hypotheses are formulated:

- Hypothesis 1a: For high growth firms, the positive effects of knowledge-based agglomeration externalities outweigh the negative externalities.
- Hypothesis 2a: For low growth firms, the negative effects of knowledge-based agglomeration externalities outweigh the positive ones.

2.3 Previous empirical studies

The spatial dimension of knowledge-based externalities has been widely studied and the contention that firms are affected by their local environment is well established (Florida 1995; Storper 1997; Gertler 2003; Malmberg and Maskell 2006; Nooteboom 2006). A large number of qualitative case studies have provided valuable insights into the dynamics and effects of agglomeration and clustering (e.g. Porter 1990; Saxenian 1994) as well as managerial and policy implications of such phenomena. These studies lend substantial conceptual support that local knowledge density (access to knowledge and skills) in general has a positive effect on firms' competitiveness and performance.

In line with the conceptual work and rich case study evidence, several quantitative studies have shown that economic activities such as patenting (Jaffe et al. 1992; Audretsch and Feldman 1996b; Singh 2013), research networks (Owen-Smith and Powell 2004), trade and production (Krugman 1991), and labor flows (Breschi and Lissoni 2001) are indeed highly collocated in space:

> "What is the most striking feature of the geography of economic activity? The short answer is surely concentration… production is remarkably concentrated in space." (Krugman 1991 p.5)

However, surprisingly few large scale empirical studies have investigated the predicted positive effects of knowledge-based agglomeration externalities on firm performance. Furthermore, amongst the studies that do exist, the results are mixed.

In a study on biotechnology agglomerations in the US, DeCarolis and Deeds (1999) find that location in an agglomeration is a significant predictor of firm performance. In a more recent study on the same industry, Folta et al. (2006) also show a positive relationship between cluster size (i.e. number of biotech firms in the region) and firm performance in terms of ability to innovate through patenting, attracting alliance partners and private equity partners. However, the marginal effects from clustering decline with the size of the cluster, which is argued to be an effect of rising negative externalities. Outside the US, Molina-Morales (2001) provide evidence that firms in the Spanish ceramic tile industry perform better when located in clusters. However, in a study on export performance in Swedish firms Malmberg et al. (2000) find only a moderate positive effect from localization economies. Kukalis (2010), in a study of the semiconductor and pharmaceutical industries in Canada, finds no evidence that clustered firms outperform isolated (non-clustered) firms in terms of financial performance. In fact, his results indicate that isolated firms outperform clustered firms in some stages of the industry life cycle.

More recently, studies have increasingly considered firm-level and/or regional-level heterogeneity when analyzing the relationship between firm performance and clustering. In a survey of 2,009 firms in the Netherlands, Knoben et al. (2016) analyze both firm-level and cluster-level heterogeneity and find that that the relationship between clustering and firm performance is moderated by firm size, internal knowledge base, and face-to-face contacts. Rigby and Brown (2015) have a similar focus when using Canadian data on manufacturing firms to investigate to what extent cluster effects differ with firm characteristics (age, size, foreign-ownership and single/multi-plant). Their results suggest that while most manufacturing plants benefit from co-location, the effects differ by plant characteristics. In a large-scale study on Swedish firms Grillitsch and Nilsson (2016) find evidence that firms with weak in-house capabilities benefit from local knowledge spillovers while firms with strong in-house capabilities perform equally well in knowledge peripheries. This is in line with Shaver and Flyer (2000) and Alcácer (2006) who analyze firms' location choice and find that weak firms (in terms of internal knowledge endowment) benefit most from industry clusters while strong firms shy away from clusters. These findings have been further elaborated by Alcácer and Chung (2007, 2014). Kalnins & Chung (2004) find that in the lodging industry, firms with strong resource endowments avoid dense environments, but only when the incumbents were primarily low-resource firms. In contrast, Audretsch and Dohse (2007) amongst others find that knowledge intensive firms benefit most from collocation. This is supported empirically by McCann and Folta (2011) who provide evidence that firms with higher knowledge stocks benefit more from agglomeration in terms of patenting performance.

3 Empirical Study

3.1 The data and sample

The data used in this study is provided by Statistics Sweden and covers all firms and individuals registered in Sweden. The data for occupation, education, and location of individuals is taken from the Longitudinal Individual Database (LISA) and is used to construct our main variable of interest, knowledge-based agglomeration externalities as well as firm-level knowledge intensity. This is subsequently merged with the Database on Business Statistics (FEK), which provides us with the variables for firm-level data such as industry codes, turnover, employees, investments, financial performance etc. Each firm is then linked to the Firm Register, allowing us to locate firms' headquarters in one of the 290 Swedish municipalities. As last step, data provided by the Swedish Transport Authority enables us to calculate the regional variable that captures not only the values in the respective municipality where the firm is located but also spillovers from neighboring municipalities based on travel distance in time between municipalities.

Our analysis covers the period from 2004 to 2011, based on the availability of consistent occupational data. As a first step, we exclude micro-firms from our sample as many of these have no growth ambitions (e.g. necessity-based entrepreneurship and academics who offer consulting services on the side). We use the EU definition of micro-firms, i.e. firms with less than 10 employees on average over the time period. As a second step we exclude firms that have changed location during the observation period as this implies a change in the accessibility to knowledge available in the region, the causes and effects of which may relate to other factors not investigated in our study. Lastly, we also exclude public services, activities of households as employers, and extraterritorial organizations. In total, this gives a sample of 188,936 observations for 32,736 firms.

3.2 Measuring high and low growth firms

Three growth indicators are used: labor productivity growth, sales growth and employment growth. Sales growth and employment growth are scale indicators that capture the extent to which a firm grows in size (monetary or human resource). Sales and employment growth are interrelated indicators, though the inclusion of both provides a more comprehensive coverage of the strength of a firm. For example, the current debate on jobless growth implies a bias if only employment growth was used. These indicators are complemented by a productivity measure that captures efficiency gains accruable to strong firms even in the absence of sales and employment growth. For example, process innovations and managerial innovations may increase productivity without influencing sales or labor. Thus, we use labor productivity growth as our third indicator for firm strength.[1] The growth measures are calculated as differences in the log of the respective value for the current and preceding period as follows:

$$lp\_growth_{it} = log(value\_added_{it+1}/employment_{it+1}) - log(value\_added_{it+0}/employment_{it+0}) \quad (1)$$

$$e\_growth_{it} = log(employment_{it+1}) - log(employment_{it+0}) \quad (2)$$

$$s\_growth_{it} = log(sales_{it+1}) - log(sales_{it+0})) \quad (3)$$

where i denotes $1,\ldots,n$ firms and t the year of observation.

[1] We are aware that the mentioned growth measures are not fully adequate for all firms. However, these growth measures offer the advantage of being available for all firms that are registered in Sweden. Also, we maintain that the chosen growth measures are relevant for most non-micro firms when they enter into market competition. Hence, it allows us to conduct a large-scale empirical study including the whole population of firms.

3.3 Measuring knowledge-based agglomeration externalities

Our indicator for knowledge intensity is based on occupational data. Occupations group together jobs that are similar in terms of tasks and duties as well as the required skill level and skill specialization to carry out the tasks and duties. As compared to educational data, which often is outdated, occupations are a timelier and more accurate measure of knowledge based on the actual work currently performed by individuals. Compared to patent and R&D data, which refer largely to a specific type of codified and science-based knowledge, occupational data captures knowledge more broadly and is relevant for all industries and firm sizes. Furthermore, occupational data has the advantage of being available as registry data for all individuals, which in turn can be linked to employers and locations.

The Swedish Standard Classification of Occupations (SSYK) is aligned to the ISCO and classifies jobs in major, sub-major, minor and unit groups. In this paper, we use SSYK-96 (consistent with ISCO-88) that defines ten major groups, each of which is associated with a specific skill level reflecting the level of education that is required in order to perform a job. In order to capture knowledge relatively broadly we classify all Professionals (jobs requiring 3-4 year university education that leads to an academic degree) and Technicians and associated professionals (jobs requiring ≤ 3 year postsecondary education [e.g. college] not leading to an academic degree) as qualified labor.

In order to not only capture the absolute number of skilled people in a region, i.e. a generic measure of agglomeration, we measure regional knowledge density as follows:

$$r\_density_{mt} = \frac{(qualified_{mt} + \sum_{s=1}^{n} qualified_{st} e^{-\lambda t_{ms}})}{(employment_{mt} + \sum_{s=1}^{n} employment_{st} e^{-\lambda t_{ms}})} \times 100 \qquad (4)$$

Where $r\_density_{mt}$ denotes regional knowledge density, $qualified_{mt}$ the total number of qualified labor and $employment_{mt}$ the total number of employed in municipality m $(m=1,...,290)$ in year t. Basing the regional variables only on municipal data would, however, introduce a sever bias because municipalities differ greatly in terms of area (from 9 to 19,000 km^2) and population (from 2,500 to over 750,000 inhabitants). Furthermore, knowledge spills over not only within a given administrative region but also between regions. Hence, we include spillovers from other municipalities s $(s=1,...,289)$. The values for qualified labor and employment in other municipalities s are discounted by an exponential distance decay function $e^{-\lambda t_{ms}}$. λ is a parameter for the sensitivity of knowledge spillovers to time distance t_{ms}, i.e. the travel distance in minutes between municipalities m and s by car. Based on previous empirical studies (Hugosson 2001; Andersson and Karlsson 2007), the λ is set to 0.017.[2]

[2] A number of empirical papers study performance differentials between firms inside and outside clusters (De Carolis and Deeds 1999; Folta et al. 2006; Eriksson and Lindgren 2009). Cluster studies require the researcher

3.4 Control variables

At the regional level, we control for agglomeration externalities that are not knowledge-based by including the log of the regional population density (nighttime population divided by the area). This includes urbanization economies that can either be positive like access to markets, finance, culture, etc. or negative like traffic jams, real estate prices, or crime rates (Parr 2002). At the level of the firm, we account for the knowledge intensity of firms through the share of qualified labor in total employment of the firm. Furthermore, we control for firm size measured as log of the total number of employees. The operating margin (earnings before interest, tax, depreciation and amortization divided by turnover) influences on the one hand the ability of a firm to finance growth and on the other hand affects the entry and exit of firms in the respective market segment, thereby influencing growth prospects. Investments in machines and equipment per employee in 100,000 SEK is included to control for growth induced by augmented capital endowments. We further account for industry fixed effects at the 2-digit NACE level (77 categories) and year fixed effects. Descriptive statistics of the included variables are reported in Annex 1.

3.5 The model

The results are based on quantile regressions (Koenker and Bassett 1978; Koenker and Hallock 2001), which allow investigating the relationship between regional knowledge intensity and growth for different quantiles in a growth distribution. The upper quantiles represent the high growth firms and the lower quantiles capture the low growth firms. Hence, we are not interested in the effects for an average firm (typically modeled by OLS, random effects or fixed effects models) but the effects of regional knowledge intensity at the tails of the growth distribution. Due to the panel structure of our data, we estimate the following model with pooled quantile regressions (Parente and Santos Silva 2016) and standard errors clustered at the level of firms:

$$growth_{it} = \alpha r\_intensity_{mt} + \beta r\_control_{mt} + \gamma f\_controls_{it} + \omega z_t + \varepsilon_{it} \qquad (5)$$

where i denotes a firm, t a year and m a region. The dependent variable $growth_{it}$ refers to labor productivity, sales or employment growth and is explained by regional knowledge intensity ($r\_intensity_{mt}$), a regional control variable ($r\_control_{mt}$) capturing population density, a vector of firm level control variables ($f\_controls_{it}$), year fixed effects (z_t) and errors (ε_{it}). Firm level control variables include firm knowledge intensity, operating margin, investments, size, and industry dummies as defined above. As firm knowledge intensity and size feature a curvilinear relationship with growth, squared terms of these variables are included.

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to define the cluster and its borders and place firms within our outside clusters (typically in binary terms). The continuous measure adopted here eliminates the well-acknowledged problem of defining cluster boundaries.

4 Results

Table 2 presents the full model with labor productivity as dependent variable. The main finding is that high growth firms grow even faster when located in knowledge-dense regions while the opposite pattern is found for low growth firms. In other words, we find support for that positive knowledge-based agglomeration externalities outweigh the negative ones for strong firms (hypothesis 1a). Weak firms, however, appear to suffer more from negative externalities than they gain from positive externalities (hypothesis 2a). This means that low growth firms perform better in knowledge-sparse regions (knowledge peripheries) than in dense environments regardless which performance measure is used.

To better understand the relationships indicated by the coefficients, the expected effect on firm growth can be illustrated for a set of typical locations in Sweden. The capital region of Stockholm and the university town of Lund, in southern Sweden, represent municipalities with high knowledge density (44% and 37% highly qualified labor respectively). In northern Sweden, Kiruna represents a city with low knowledge density (29%) while the city of Karlskrona represents a region with mid-level knowledge density (33%) (see map in Annex 2).

The results presented in Table 2 imply that high growth firms (90^{th} percentile) located in Stockholm, Lund or Karlskrona are expected to further boost their labor productivity by 11 percentage points, 6 percentage points and 3 percentage points respectively as compared to other high growth firms located in Kiruna. Conversely, the weakest firms (10^{th} percentile) located in Stockholm, Lund or Karlskrona are expected to experience respectively 8 percentage points, 4 percentage points and 2 percentage points *lower* labor productivity growth than similar firms in Kiruna. The patterns for sales and employment growth are similar, though the effects are smaller in magnitude.

Table 2 Quantile Regressions: Regional knowledge density on labor productivity growth

	Labor Productivity Growth				
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Variables	*Low growth*				*High growth*
Regional knowledge density	-0.5015***	-0.1981***	0.0262	0.2475***	0.7202***
	(0.0537)	(0.0226)	(0.0161)	(0.0233)	(0.0786)
Population Density (ln)	-0.0026	-0.0018*	-0.0006	-0.0015	-0.0054***
	(0.0019)	(0.0009)	(0.0006)	(0.0010)	(0.0019)
Firm knowledge intensity	-0.2890***	-0.1199***	0.0037	0.1253***	0.2907***
	(0.0222)	(0.0105)	(0.0069)	(0.0109)	(0.0230)
Firm knowledge intensity (square)	0.3154***	0.1330***	0.0022	-0.1225***	-0.2971***
	(0.0252)	(0.0124)	(0.0083)	(0.0124)	(0.0254)
Operating Margin	-0.1086***	-0.2513***	-0.3350***	-0.4310***	-0.4750*
	(0.0371)	(0.0736)	(0.0709)	(0.1121)	(0.2647)
Investments / employee	-0.0031	0.0009***	0.0020***	0.0062***	0.0122***
	(0.0060)	(0.0001)	(0.0005)	(0.0011)	(0.0021)
Size (ln)	0.0985***	0.0279***	-0.0196***	-0.0870***	-0.1930***
	(0.0096)	(0.0043)	(0.0022)	(0.0047)	(0.0108)
Size (ln) (square)	-0.0093***	-0.0020***	0.0020***	0.0084***	0.0195***
	(0.0013)	(0.0005)	(0.0003)	(0.0006)	(0.0015)
Constant	-0.3394***	-0.1091***	0.0771***	0.2963***	0.5588***
	(0.0364)	(0.0192)	(0.0136)	(0.0193)	(0.0762)
Industry dummies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	188936	188936	188936	188936	188936
Clusters (firms)	32736	32736	32736	32736	32736

Note: Standard errors clustered at the level of the firm in parentheses; ***, **, * denotes significance at the 1%, 5%, and 10% levels.

As regards the control variables, it becomes apparent that location in an area with a high population density has no significant effect for most firms and a negative effect for high growth firms, i.e. suggesting negative non-knowledge specific agglomeration effects such as congestion. The results for firm-level control variables underline the importance of examining relationships at different points in growth distributions. More specifically, the relationships between typical explanatory variables (i.e. firm-knowledge intensity, operating margin, investments, and firm size) and firm growth differ substantially by firms with different growth levels. While this finding per se may not be surprising it challenges traditional methods that investigate effects at the means of distributions. For instance the relationship between firm knowledge intensity and firm growth changes from a u-shaped (low growth firms) to an inversed u-shaped (high growth firms) form. Investments have no effect on growth for low growth firms firms but contribute positively to firm performance of high growth firms. The operating margin affects low growth firms negatively; this negative effect becomes less significant for high growth firms. Coad and Rao (2008) report similar patterns for the relationship between R&D and growth and argue that this relates to the fact that R&D expenses only have a positive effect if they lead to innovations. Failed innovative activities are sunk costs and can even threaten the existence of firms.

Table 3 compares the effects of regional knowledge density on the three different performance measures, labor productivity, sales and employment growth. The pattern observed for labor productivity is reproduced also for sales and employment growth albeit with lower magnitude. Still, the differences are substantial. Location in Stockholm contributes 9 percentage points to sales growth and 5 percentage points to employment growth as compared to a location in Kiruna for strong firms (90^{th} percentile). The negative effects are smaller; weak firms (10^{th} percentile) experience a negative sales and employment growth effect of 3 percentage points if located in Stockholm as compared to regions with low regional knowledge density.

Table 3 Quantile Regressions: Regional knowledge density on labor productivity, sales and employment growth

	Effects of regional knowledge density on firm growth at the				
Dependent variable	10^{th} Percentile Low growth	25^{th} Percentile	50^{th} Percentile	75^{th} Percentile	90^{th} percentile High growth
Labor Productivity Growth	-0.5015***	-0.1981***	0.0262	0.2475***	0.7202***
	(0.0537)	(0.0226)	(0.0161)	(0.0233)	(0.0786)
Sales Growth	-0.1973***	-0.0290	0.0652***	0.2389***	0.5895***
	(0.0448)	(0.0187)	(0.0158)	(0.0264)	(0.0595)
Employment Growth	-0.1876***	-0.0786***	0.0228*	0.1309***	0.3011***
	(0.0381)	(0.0213)	(0.0127)	(0.0219)	(0.0378)

Note: Standard errors clustered at the level of the firm in parentheses; ***, **, * denotes significance at the 1%, 5%, and 10% levels. Regressions are based on 188,936 observations and 32,736 firms.

In order to test and investigate the results, a number of robustness checks have been undertaken. These include splitting the sample into firms with and without qualified labor in-house, small and large firms, and manufacturing and service firms. Furthermore, the regressions were run with a more narrow definition of qualified labor. The result of these robustness checks is that the reported patterns prevail. The most interesting difference, however, emerged between manufacturing and service firms (Table 4). In particular, strong service firms tend to grow significantly faster in knowledge-dense environments than strong manufacturing firms. The expected effects of regional knowledge density on labor productivity and sales growth are approximately double for high growth service firms. Strong service firms also grow more in terms of employment if located in knowledge-dense regions whereas such an effect cannot be confirmed for manufacturing firms. In contrast, weak service and manufacturing firms show similar negative relationships with regional knowledge density. This means that for manufacturing firms, there are substantial negative knowledge-based agglomeration externalities for low growth firms while the positive externalities for high growth firms are relatively small. An explanation for the observed differences between high growth manufacturing and service firms is that knowledge in manufacturing industries to a larger extent than for service firms is embodied in machinery and organizational processes. This would imply a stronger reliance on knowledge based-agglomeration externalities for service firms as compared to manufacturing firms (Raspe and Van Oort 2008; Vega-Jurado et al. 2009).

Table 4 Quantile Regressions: Regional knowledge density on labor productivity, sales and employment growth by sector

	Effects of regional knowledge density on firm growth at the				
Dependent variable	10th Percentile Low growth	25th Percentile	50th Percentile	75th Percentile	90th Percentile High growth
Manufacturing Firms					
Labor Productivity Growth	-0.3913***	-0.1593***	-0.0402	0.0597	0.3450***
	(0.1110)	(0.0616)	(0.0436)	(0.0556)	(0.1207)
Sales Growth	-0.1732*	-0.1149**	-0.0253	0.0863	0.2829**
	(0.0964)	(0.0484)	(0.0398)	(0.0612)	(0.1243)
Employment Growth	-0.1619**	-0.0796**	-0.0769**	-0.0079	-0.0498
	(0.0768)	(0.0402)	(0.0367)	(0.0431)	(0.0785)
Service Firms					
Labor Productivity Growth	-0.4768***	-0.1844***	0.0214	0.2620***	0.7265***
	(0.0621)	(0.0281)	(0.0181)	(0.0277)	(0.0703)
Sales Growth	-0.1612***	-0.0349	0.0494***	0.1839***	0.5484***
	(0.0532)	(0.0221)	(0.0183)	(0.0318)	(0.0799)
Employment Growth	-0.1365***	-0.0655**	0.0260	0.1349***	0.2482***
	(0.0499)	(0.0268)	(0.0179)	(0.0291)	(0.0467)

Note: Standard errors clustered at the level of the firm in parentheses; ***, **, * denotes significance at the 1%, 5%, and 10% levels. Regressions for manufacturing firms are based on 41,117 observations and 6,681 clusters; service firms on 116,918 observations and 20,769 clusters. Manufacturing firms encompass the SNI codes 10-33; service firms the SNI codes 45-63, 68-82, 85-96.

5 Concluding discussion

Our study shows that positive agglomeration-based knowledge externalities outweigh negative ones for high growth firms, i.e. they tend to grow even faster in knowledge-dense regions. The opposite is found for weak firms, which tend to grow less (or shrink faster) in knowledge-dense regions than if located in the knowledge periphery. This means that agglomeration-based knowledge externalities, stemming from local knowledge spillovers and local labor market dynamics, further widen the performance gap between strong and weak firms. This has profound implications for firms and industrial dynamics as the reallocation of resources from low growth to high growth firms, thereby from low to high-value economic activities, unfolds quicker in knowledge-dense regions. These results hold for employment, sales, and labor productivity growth alike.

The paper carves out two key theoretical arguments that underlie the scientific debate on knowledge-based agglomeration externalities. The *knowledge equilibrium argument* predicts that knowledge externalities weaken strong firms and strengthen weak firms until knowledge equilibrium is achieved. The *knowledge competition argument* suggests that strong firms are in a better position to identify, attract, and integrate new knowledge and skills and thus benefit more from knowledge externalities. In the empirical contest, the *knowledge competition argument* came out first.

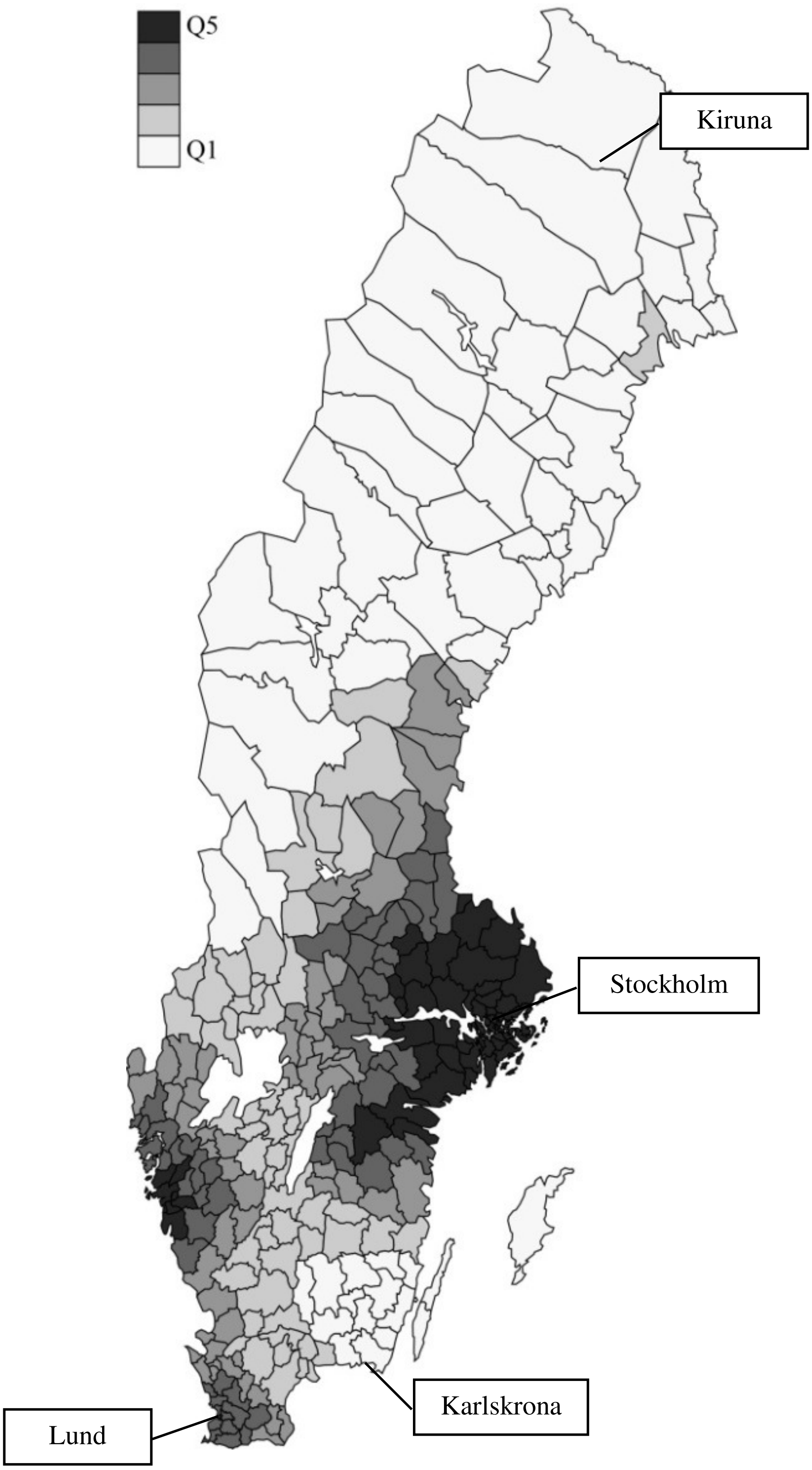
However, the battle between the two arguments is not yet decided and the outcome may depend among other things on regional, industrial, and firm-specific factors. The study was undertaken in Sweden, a country persistently ranking top in indicators on country innovativeness but also factor cost. Firm survival and growth can thus not rest on price competition but on creating higher value through innovation. Within such an empirical context, it appears plausible that the *knowledge competition argument* weighs more than the *knowledge equilibrium argument*.

The knowledge equilibrium and *knowledge competition arguments* also relate to the literature on technological trajectories and industry life cycles (Dosi 1982; Audretsch and Feldman 1996a; Klepper 1997; Kukalis 2010). On the one hand, knowledge externalities can contribute to increasing standardization (i.e. erasing differences between firms) in maturing technologies and industries, thereby leading to increasingly homogenous products and intensified price competition. On the other hand, knowledge externalities can promote innovation (i.e. the generation and novel combination of knowledge) thereby augmenting differences between firms. Also, the relative importance of the two arguments may depend on characteristics of the knowledge firms employ in innovation processes. If knowledge devaluates quickly (e.g. market knowledge in the fashion industry) being in a knowledge-dense region may be more important than if knowledge devaluates relatively slowly (e.g. technological knowledge in a traditional manufacturing industry) (Shearmur 2015).

Annex 1: Descriptive Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9
1 Labor productivity growth	188,936	0.035	0.376	-7.114	8.107	1.000								
2 Employment growth	188,936	0.023	0.326	-7.164	5.799	0.020	1.000							
3 Sales growth	188,936	0.078	0.371	-8.316	6.307	0.320	0.394	1.000						
4 Regional knowledge density	188,936	0.377	0.042	0.282	0.463	0.005	0.000	0.000	1.000					
5 Firm knowledge intensity	188,936	0.207	0.272	0.000	1.000	0.007	0.030	0.017	0.260	1.000				
6 Operating margin	188,936	0.079	0.573	-69.91	105.97	-0.072	0.012	0.007	-0.008	-0.002	1.000			
7 Investments	188,936	0.588	4.899	-1.145	1206.9	0.007	0.035	0.016	-0.012	0.004	0.025	1.000		
8 Size	188,936	3.156	0.934	0.000	10.01	-0.023	-0.167	-0.077	0.052	0.083	-0.002	0.010	1.000	
9 Population density	188,936	3.793	0.844	0.067	4.728	0.003	0.015	0.007	0.614	0.223	-0.009	-0.014	0.052	1.000

Annex 2: Regional knowledge intensities (λ=0,017) represented in five quantiles (Q1/Q5 represents low/high regional knowledge intensity)



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