The trade-off between absorptive capacity and appropriability of the returns to innovation effort

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Abstract

A key concept in the economics of innovation is the 'public good' nature of knowledge. This generates a tension between incentivizing knowledge production by allowing knowledge creators appropriate the economic benefits and encouraging its diffusion to enhance the social return to knowledge creation. Where firms operate in localities that are characterized by greater entrepreneurship, there may be lower incentives to engage in research and development. This would result from a higher risk of knowledge spillovers to local start-ups and/or that employees may exploit new knowledge in spin-out firms. It has also been suggested in the literature that greater local entrepreneurial activity may lower profits for incumbent firms, through greater competition and/or the leakage of commercially valuable new knowledge. This paper presents a novel conceptual perspective on this tension and empirically tests it. Using Swedish firm-level data and county-level data on new start-ups, this paper estimates the effect on R&D activity of local rates of business start-ups. It finds that greater numbers of new start-ups in a metropolitan area reduces firm-level R&D expenditure. However, this relationship is not linear, so that at higher levels of new firm formation in a region, firm-level R&D expenditure falls at a diminishing rate. This suggests that the effect of local entrepreneurship on a business' R&D decisions is conditioned by the extent of that entrepreneurship.

Keywords: Innovation, entrepreneurship, absorptive capacity, knowledge spillovers
JEL Codes: R11, O33, O31

1. INTRODUCTION

As a result of the only partially excludable nature of new knowledge (Romer 1990), businesses may be unable to appropriate for themselves the full benefit of an innovation. In other words, innovations may generate benefits for businesses or industries other than the businesses and industries in which they were created, for which the innovator is not compensated. There are many examples of this, such as the impact on many industries of the development of the personal computer. The generation of new knowledge creates a private return for the innovator, but also a social return. In this context, as with all public goods, the level of investment in innovation may be less than the socially-optimal level. The approaches to solving this market failure include government funding for or direct provision of research, for example in third-level institutions and the granting of monopoly patent rights to enable businesses to appropriate some of the benefits of innovation.

This generates a tension for policy makers between incentivizing knowledge production; by allowing innovators to appropriate the economic benefits, and encouraging its diffusion to enhance the social return to knowledge creation. Businesses, of course, also face a strategic innovation decision, which is conditioned by their ability to capture the returns from research and development and the ability to access and exploit knowledge generated externally, including that generated by other businesses. What we are referring to here is essentially the trade-off between the appropriability regime (Hurmelinna-Laukkanen and Puumalainen, 2007a and 2007b) and absorptive capacity (Cohen and Levinthal, 1990).

There are also spatial aspects to this trade-off, since geographic proximity may enhance the ability of businesses to learn from each other and benefit from others' knowledge creation. As Glaeser et al. (1992) noted "intellectual breakthroughs must cross hallways and streets more easily than oceans and continents". In this regard, proximity may be a double-edged sword, where businesses benefit from absorbing the knowledge generated by others, but risk leakage of their own knowledge creation to others. This tension is explored in this paper, using entrepreneurial start-up data for Swedish metropolitan areas. The analysis estimates whether a business' innovation effort is helped or hindered by spatially weighted innovation effort of proximate businesses and the level of entrepreneurial new business start-ups in the metropolitan area in which it is located.

The next section describes the novel conceptual and theoretical drivers of the paper, elaborating on the trade-off between appropriability and absorptive capacity for innovation active businesses. This is followed by a description of the data used to estimate the relationship between the entrepreneurialism of the area and close businesses' innovation effort on a business' own innovation effort. The spatial econometric estimation techniques are described and the results presented in the following section. A concluding section discusses the results and their implications.

2. APPROPRIABILITY AND ABSORPTIVE CAPACITY

In a general equilibrium context, the objective of profit maximisation provides an incentive to businesses to engage in research and development (R&D) when the returns from the investment are seen to outweigh the costs (Nelson, 1991). In practice however, this is complicated by the inability *ex ante* to evaluate the success of R&D in generating a commercially exploitable product or process and their success in the market.

Even where a business could secure for itself all the commercial benefits of new knowledge creation, the decision to invest in R&D is fraught because innovation is a highly uncertain process. Successful innovation involves achieving technological breakthrough and economic viability (Kline and Rosenberg, 1986). The ability of firms to protect their intellectual property does not overcome this problem of uncertain commercial and technological viability. It is clear that firms engage in new knowledge creation even where they cannot evaluate or it is difficult to evaluate the commercial returns to that new knowledge. Indeed, the implication of the concept of absorptive capacity is that generating new products and processes directly is not the sole justification for investing in R&D (Cohen and Levinthal, 1990).

Cohen and Levinthal (1989 and 1990) argue that there are indirect benefits from R&D effort. Firms also engage in R&D activity to build up their absorptive capacity. This is the ability of employees within the business to identify, evaluate, and exploit new technological opportunities from outside the business. This includes absorbing potentially useful knowledge generated by research institutions, universities and/or other businesses.

This means firms may increase investment in R&D activity to enable them to use and potentially appropriate some of the returns to knowledge creation outside of their businesses.

This ability to identify and exploit external knowledge may also be enhanced by a firms' proximity to the sources of that knowledge. For instance, the potential to perceive and evaluate this external knowledge may also be enhanced by co-location or spatial proximity.

It is well established within the literature that closer proximity improves the transmissibility of knowledge. Indeed a long-standing and key motivation and explanation for spatial concentration of economic activity is the potential for knowledge spillovers (Marshall, 1890, Jacobs, 1969, Porter, 1990, Fujita et al., 1999). Audretsch and Feldman (1996) find that "innovative activity is more likely to occur within close geographic proximity to the source of that knowledge, be it a university research laboratory, the research and development department of a corporation, or exposure to the knowledge embodied in a skilled worker". They also find that those industries for which new knowledge is important tend to concentrate spatially, and that this is attributable to knowledge spillovers rather than just the concentration of production.

There is also substantial empirical support for geographically bounded knowledge spillovers within the innovation and regional economics literatures (for example (Crowley and Jordan, 2017, Johnston and Huggins, 2017, Doran et al., 2012, Grillitsch et al., 2017, Broekel and Mueller, 2018, Cardamone, 2018, Neves and Sequeira, 2018). There is also evidence of a strong demonstration and contagion effect in entrepreneurship which may be spatially bounded (Nikolaev and Wood, 2018).

Aghion et al. (2005) examined the relationship between product competition and innovation. They found strong evidence of an inverted U-shaped relationship where laggard firms are discouraged to innovate and neck-and-neck firms are encouraged to innovate. Crowley and Jordan (2017) also consider the relationship between the amount of competition and firm-level innovation output, and find that more competition is associated with more firm-level innovation, but at a diminishing rate. They find however a local rivalry effect, such that increased competition in local markets increases innovation output. This suggests a positive relationship between the number of local competitors and innovation.

It is common for geographic proximity to be referred to predominantly as a positive effect for the flow of knowledge between firms in a location. However, where firms wish to retain the knowledge generated by their R&D activities, such proximity is problematic. (Howells, 2002) refers to unintended, informal knowledge spillovers that are facilitated by geographical proximity, where the owners of knowledge cannot prevent others from making use of it. Of particular relevance is the mobility of highly skilled employees to other firms in a region or to set up new firms as a means of knowledge being lost to its owner (Grossman and Helpman, 1993).

In a more nuanced study, (Crescenzi and Gagliardi, 2018) explore the complementarity between internal and external sources of knowledge for a firm. They find that firms located where there are clusters of more knowledgeable individuals (measured by the location of patent holders) are not more innovative than otherwise. Firms that have stronger potential and realised absorptive capacity can benefit from combining internal and external knowledge sources.

This reflects the tensions that exist in relation to firms' knowledge creation activities, such as R&D and innovation. It may be beneficial for firms to be located close to other organisations that generate new knowledge, so that they can learn about and from this new knowledge more easily. However, firms that generate new knowledge may be adversely affected by being located close to other firms into which their own knowledge and commercial returns may spill over. While R&D active firms may benefit from being close to other R&D active firms, this of course increases the risk of not being able to appropriate all of the return from their own R&D investment.

Colombo and Dawid (2016) argue that business' incentives to invest in R&D may be reduced because of the knowledge loss occurring through start-up formation in their region/city. They argue that more businesses in entrepreneurial locations, measured by new firm formation, will invest less in R&D, due to the risk of knowledge loss.

Agarwal et al. (2007) emphasise that incumbent firms are a source of new start-ups, specifically when incumbents are unable to fully appropriate the benefits of the knowledge they generate. (Klepper, 2001), in discussing employee start-ups in high-tech industries, refers to the potential adverse effect of such spin-offs on the incentives and capacity for incumbent firms to innovate. An entrepreneurial region that provides an enhanced environment that favours start-ups may simultaneously result in existing regional firms R&D activity being lower than it would otherwise be if the regions did not have a 'start-up culture'.

In a recent US study, Babina and Howell (2018) find that firms' R&D investment leads to new start-ups by employees departing to launch their own firms, referred to as entrepreneurial spawning. In addition they assert that, since the emergence of the new start-ups appears to have no observable cost to the firm the entrepreneurs left, the spawning is a conduit for knowledge spillovers. These spillovers also tend to be geographically bounded and are another source of agglomeration of economic activity.

The spillover of knowledge through entrepreneurial spawning has implications for innovation outcomes in the firms that new business owners leave. Kim and Marschke (2005) analyse the relationship between a firm's propensity to patent and the likelihood of high-skilled employees to join or start a rival firm. They find that employee mobility "within geographical regions has a pronounced effect on patenting is consistent with evidence elsewhere of localized technological spillover effects" (2005). Using data from the Italian Community Innovation Survey, Colombo et al. (2017), find that firms spend less on R&D where there are better complementary assets for new venture start-ups. These assets are proxied by the extent to which financial resources are available for new start-ups.

We conclude that businesses face a trade-off when investing in R&D between the potential risks of new knowledge being lost to other proximate businesses and the potential gains from knowledge spillovers from proximate businesses.

We hypothesise that businesses may benefit from greater knowledge generation in highly entrepreneurial locations. The "knowledge in the air" (Marshall, 1890) increases the value of absorptive capacity. The more firms that are located within an area, the more knowledge that's available to spillover.

This suggests a U-shaped relationship between a business' R&D effort and the degree of entrepreneurship in its location. This relationship is represented in Figure 1.

[Figure 1 here]

The tension discussed above between firms' knowledge gains from other firms in proximity and the risk of loss of knowledge from proprietary R&D to close firms suggest two propositions to be tested in subsequent sections of this paper. First, following Colombo and Dawid (2016), firms will invest less in R&D in more entrepreneurial regions due to the risk of loss knowledge to other firms. Here, appropriability outweighs absorptive capacity. Second, as the number of new firms in a region increases, firms will increase spending on R&D to exploit potential knowledge flows from these new start-ups. At some point, absorptive capacity outweighs appropriability.

There are potentially important policy implications for urban development from this analysis, where the start-up culture promoted in the entrepreneurial cities framework (McNeill, 2017, Hall and Hubbard, 1996, Harvey, 1989) may have the effect of undermining R&D activity. Perhaps there may be a tipping point at which more start-ups generate the expected benefits from an entrepreneurial city, though it is important for city managers to understand the dynamics of the relationship between firm R&D effort and start-ups within the entrepreneurial eco-system (discussed in Spigel and Harrison (2018)).

The next section presents the data and method used to test the propositions above and the subsequent section presents the results of the analysis and discusses the implications.

3. DATA AND METHOD

To test the hypothesis of a U-shaped relationship between firm innovation effort and the entrepreneurialism in the firm's city region, this paper uses two sources of data. First, firm-level data is gathered from the World Bank's Swedish Enterprise Survey (SES) 2014. This was a survey of business owners and top managers in 600 firms conducted between January 2014 and November 2014. The survey was based on a representative sample of firms by size, region, and sector, using a stratified random sampling technique. The SES collects data on firm characteristics, firm performance, and perceptions of the business environment.

The SES includes the exact geographical location of the firm by latitudinal and longitudinal coordinates. The sampled firms are dispersed geographically between four main regions: with just under a third in the Linkoping-Orebro-Karlstad-Vasteras region and a similar number in the Boras-Gothenborg-Jankoping-Trollhattan region. The Stockholm-Solna region has the fewest firms with just under one fifth of the total. The locations of the sampled firms have coverage across 103 municipalities of the 290 possible municipalities in Sweden. Their municipality location is displayed in Figure 2. The exact location is not reproduced due to the sensitive nature that exact location may reveal for an individual firm. The locations of most of the firms correspond to the main functional urban regions of Sweden (OECD, 2016) which are based on commuting patterns as presented in Figure 3.

The definitions of the variables to be used for the analysis are presented in Table 1. Table 2 presents descriptive statistics for the firms in the survey. The average R&D spend per worker for the sample of firms is 28,810 in SEK currency units. Just under 40 per cent of the firms in the sample perform R&D. Figure 4 displays a heat map of the average log of R&D expenditure per worker of the sampled firms at the level of each municipality. The colours in the map do not strongly point to any significant pattern of non-random spatial clustering. We further construct technology and knowledge intensive indicators for the sample of firms using the Eurostat (2014) indicators of high technology and knowledge intensive services definition. In our sample, 26 per cent of the firms are categorised as medium to high knowledge intensive manufacturing or service firms. 14 per cent of this category of firms' exports their products. This is relative to just over a quarter of all sampled firms being exporters. The average age of firms in our sample is 39 and the average number of employees is 104. Of the sample, 40 per cent are service firms.

[Table 1 and 2 here]

[Figure 2 here]

[Figure 3 here]

[Figure 4 here]

[Figure 5 here]

The second data set is on firm start-ups which was collected by the Swedish Agency for Growth Policy Analysis (2018). This provides information on the number of new start-ups by year for each of Sweden's 290 municipalities. Figure 4 shows the number of new firm start-ups by municipality for 2013. There are 290 municipalities and there were 69,242 new firms created across all municipalities in 2013. For this indicator, there seems to be a pattern of non-random spatial clustering of new firms, particularly in the Stockholm-Solna region.

For the analysis, we use the average number of new firm start-ups by municipality over the three year period 2011 to 2013. It is reasonable to suggest that if the R&D levels of firms are affected by the number of start-ups nearby, then it is likely their reaction has a temporal lag. So, we use a three year average measure of firm start-ups for each municipality, which encompasses a two year period up to when the firms were surveyed and the year in which the firms were surveyed.

Given the stratified nature of SES, we have firm level data and corresponding new firm start-up data for 103 of these municipalities. There was an average of 990 new firms created per municipality over the 2011 to 2013 period. The lowest average number recorded was in Munkfors (14) and the highest number was in Stockholm (11,099).

The new start-up data also enables some limited sectoral breakdown. For instance, it is possible to distinguish between new firms that are manufacturing and construction or services. We include a share indicator on the percentage of new firms that are manufacturing and construction at the municipal level[1]. Table 2 shows that the average percentage of new manufacturing/construction firms was 15 per cent in 2013. The highest proportion of new manufacturing firms was 35 per cent in the municipality of Lilla Edet. This indicates that new start-ups are predominantly in service sectors, which largely replicates the patterns in other developed countries.

The effect of new firm formation on R&D activity is analysed using ordinary least squares (OLS) regression techniques and spatial autoregressive estimations (SAR). The results of each estimation are then compared for explanatory power. The latter technique is used because of the spatial nature of the data used in this study. The OLS specification is as follows:

[1] Unfortunately, it is not possible to distinguish between whether the firms are manufacturing or construction

$$R\&D_i = \beta_0 \ + \beta_1 \ NF_{ij} + \ \beta_2 \ NF_{ij}^2 \quad + \beta_k \ C_i + \ \varepsilon \qquad \text{(equation 1)}$$

In this specification, $R\&D_i$ is the dependent variable measured by the log of R&D expenditure per worker in firm i. NF_{ij} is the log of the number of start-ups in municipality j in which firm i is located. NF_{ij}^2 is the log of the number of start-ups in the municipality squared. These two variables are important for testing our hypothesis presented earlier in Section 2. C_i is a vector of explanatory variables that may affect the level of innovation effort of each firm which includes the rest if the variables outlined in Table 1.

The SAR model extends the OLS regression by allowing outcomes in one location to be affected by: (1) outcomes in nearby locations; (2) covariates from nearby locations; and (3) errors from nearby locations. Since the firms' locations are available and also since start-ups are at municipal level, the analysis can control for the effect of R&D levels of nearby firms and the intensity of start-ups in nearby municipalities may have on the level of R&D activity of the sampled firms. To control for this effect the estimation includes (1) a spatial lag of the R&D dependent variable to identify if it is affected by the R&D intensities of nearby firms; (2) a spatial lag of the number of firms by municipality, as the number of start-ups in nearby municipalities may affect outcomes in our model; and (3) spatially autoregressive errors to address the possible unobserved spatial effects affecting outcomes in our model. The specification of this model takes the form:

$$R\&D_i = \beta_0 \ + \beta_1 \ NF_{ij} + \ \beta_2 \ NF_{ij}^2 + \quad \beta_1 \ WR\&D_i + \beta_2 \ WNF_{ij} + \beta_k \ C_i + (\mathrm{I} - \rho\mathrm{W}) \ - 1 \ \varepsilon$$

(equation 2)

The difference between equation (1) and equation (2) is the inclusion of $WR\&D_i$, WNF_i and ρ (rho). $WR\&D_i$ is the spatial lag of the dependent variable. WNF_i is the spatial lag of our independent variable of interest (start-ups at municipal level). ρ (rho) is the correlation parameter of the residuals. W is the inverse distance spatial weighting matrix and its values characterize the spatial relationship between firms. It specifies the potential spillover effect from one firm location to another.

The model is further estimated with a generalised method of moments (GMM) estimator, which allows higher-order dependent variable lags and higher-order autoregressive error terms to be fit (StataCorp, 2017). Heteroskedastic standard errors are estimated for both the OLS and SAR models. We also employ the Moran's test (Moran, 1950) and Wald test for spatial dependence in our models. The results[2] of our analyses are presented in the next section.

4. RESULTS

The results of the OLS and SAR models are presented in Table 3. It can be seen from comparing the results that they are very similar. In fact, both the Moran's test of the OLS model and the overall Wald test of spatial dependence of the SAR model suggest that there is no need to control for spatial differences across observations. However, the implications of spatial effects are perhaps more nuanced than these results suggest. The Moran's I test in the OLS model is on the error term. It is also possible that the spatial spillover effect may also arise from an independent variable, which in our case may be the number of start-ups by municipality.

To examine for this, we completed additional checks, which can be found in Table 4. Following Kondo (2018), we conducted a Moran's I test on the number of start-ups per municipality and the results suggest that municipalities with higher firm formation rates have neighbours with similar characteristics. This implies a positive spatial autocorrelation in municipal firm start-up rates. As a result, it was necessary to control for the spatial lag of the covariate in our SAR model.

The SAR model identified some nuanced spatial spill-over effects. The spatial lag of the dependent variable is significant at the 10 per cent level with a negative sign suggesting that the R&D of neighbouring firms negatively affects the R&D spend of firms. Table 5 displays the average direct, indirect, and total effects from the SAR model. As can be seen, almost all the effects are direct effects from the firm's own location. The only exception is a negative indirect effect from exporting. However, this is only significant at the 10 per cent level and the marginal effect is relatively small. Following this analysis, it can be concluded that the spill-over effects are small and isolated to R&D and exporting. Even though the OLS and SAR model report very similar results, the results discussed subsequently refer to the SAR model.

[2] Sampling weights are used for each estimation.

[Tables 3, 4 and 5 here]

Starting with the variables of specific interest in this paper, the results show that, other things equal, the level of R&D expenditure in a firm is negatively associated with the number of start-ups in the same municipality at the one per cent significance level. This provides support for Colombo and Dawid (2016) who suggest the risk of leakage of new knowledge to entrepreneurial co-located start-ups would act to dis-incentivise R&D activity. The more new start-ups in a municipality the lower the amount invested by individual firms on R&D.

However, the results also indicate that the relationship between new start-ups and firm-level R&D is not linear. The squared-term for the number of start-ups is negatively associated with firm-level R&D investment. This indicates that an increase in the number of start-ups reduces firm-level R&D but at a diminishing rate. While this does not provide evidence of a U-shaped relationship, it suggests that there is a decline in the perception or threat of leakage of knowledge to proximate start-ups.

This implies a scale effect, which means that a greater number of enterprises, including start-ups, within a region dilutes the likelihood of single firms appropriating knowledge from other R&D active firms. More knowledge is ‘in the air’ but this is generated by many firms and so there may be less focus by other firms on the knowledge activities of any single firm.

It may also be that the incentive for firms to engage in R&D is increased by the presence of more other firms, including start-ups. The greater number and concentration of start-ups generates more knowledge and this makes the absorptive capacity element of R&D activity more worthwhile.

We further identify that there may be a significant sector start-up story explaining R&D dynamics at municipal level. Municipalities with higher percentages of manufacturing start-ups have firms with lower R&D expenditures. Since the pattern worldwide is for an increase in the relative importance of service sectors, this finding may be a concern for local policymakers in municipalities that have a greater share of new manufacturing start-ups. The other sectoral story is unsurprising where the results indicate that manufacturing and service firms in medium to high knowledge intensive activities are more likely to invest in R&D, relative to low to medium knowledge intensive firms.

As expected, and in line with the literature (Cohen and Levinthal, 1990; Griliches, 1998; Romer, 1990), the results demonstrate a positive association between firm-level R&D investment and firm-level human capital. The latter in this case is measured by the proportion of employees with a third-level qualification and whether the firm provides training for employees. The positive association between R&D effort and exporting is also consistent with previous studies (Roper and Love, 2002, Feldman, 1999).

Smaller firms are also more likely to spend on innovation activities. Firm size has long been established in the literature as being an important factor for firms' expenditure on R&D (Shefer and Frenkel, 2005), with both large firms and small firms found to be highly innovative (Tether, 1998).

5. DISCUSSION AND IMPLICATIONS

The analysis presented here has implications for cities that promote more start-ups as a driver of economic growth and development. A greater number of start-ups may come at a cost of less R&D investment in incumbent firms, and policy mechanisms to offset the disincentive inherent in this may be required. Such R&D supports though are frequently set at national, rather than city or regional level.

The impact on incumbent firm R&D investment is reduced by scale. That means that an increase in the number of start-ups has a diminishing marginal effect. This has implications for smaller or second-tier cities who will, by nature of their size, have fewer start-ups than capital or larger cities. Indeed, the effect seen here may go some way to explain the persistence of productivity and innovation advantages of capital city regions, though more focused analysis on that issue would be required.

None of the incumbent's sectoral variables were found to be significant, indicating that whether a firm is medium or highly technologically intensive is the main driver of a firm's R&D activities. The analysis would benefit further from even deeper sectoral breakdown of the effects beyond the dichotomy of manufacturing versus services, as it is likely that the relationship between R&D investment and start-ups will be differentiated sectorally. Some sectors, particularly high-technology or service sectors, may have a stronger start-up culture with more mobile employees.

The data on the firm start-ups does not facilitate a more granular analysis of sectoral differences, going deeper than simply manufacturing and services. Such an analysis would require a sectoral breakdown of incumbent and start-up firms. We note that this could be a particular area of interest for future research in this area. Still, the fact that municipals with greater start up levels of manufacturing firms have lower firm level R&D activity is a concern for policymakers as this may help explain any inter-regional differences in standards of living.

The insights of the analysis presented here suggest that the creation and dynamics of effects of localised knowledge spillovers from investments in knowledge creation and R&D activity are nuanced. The interdependence between firms within city regions means that entrepreneurial activity may work to hinder the production of the knowledge 'in the air' that underpins agglomeration effects for innovation.

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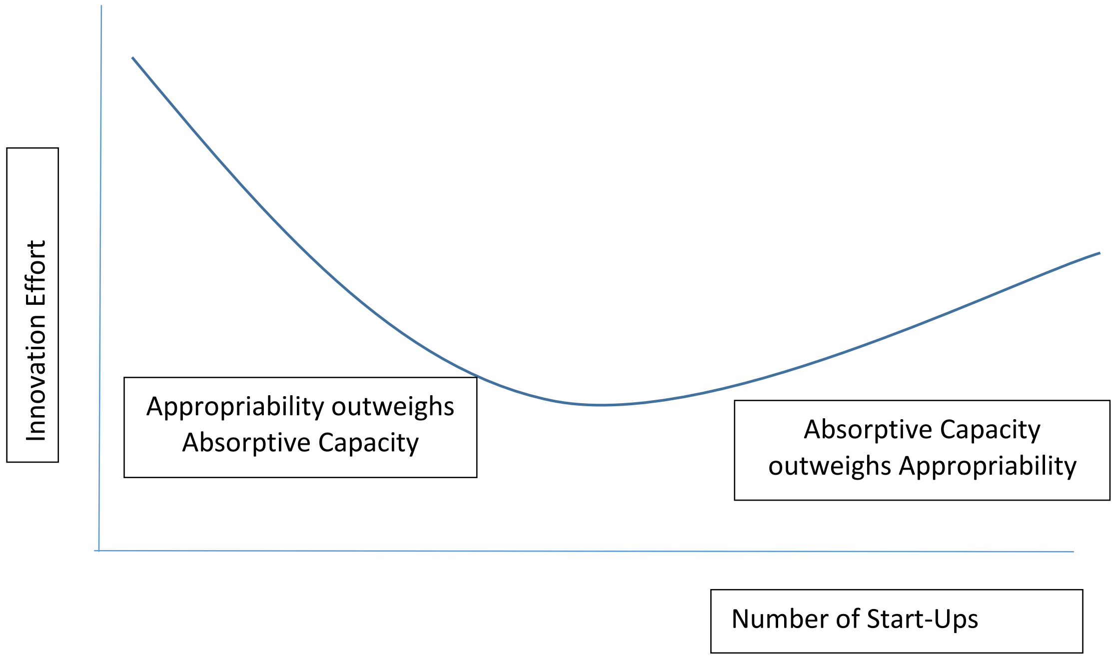
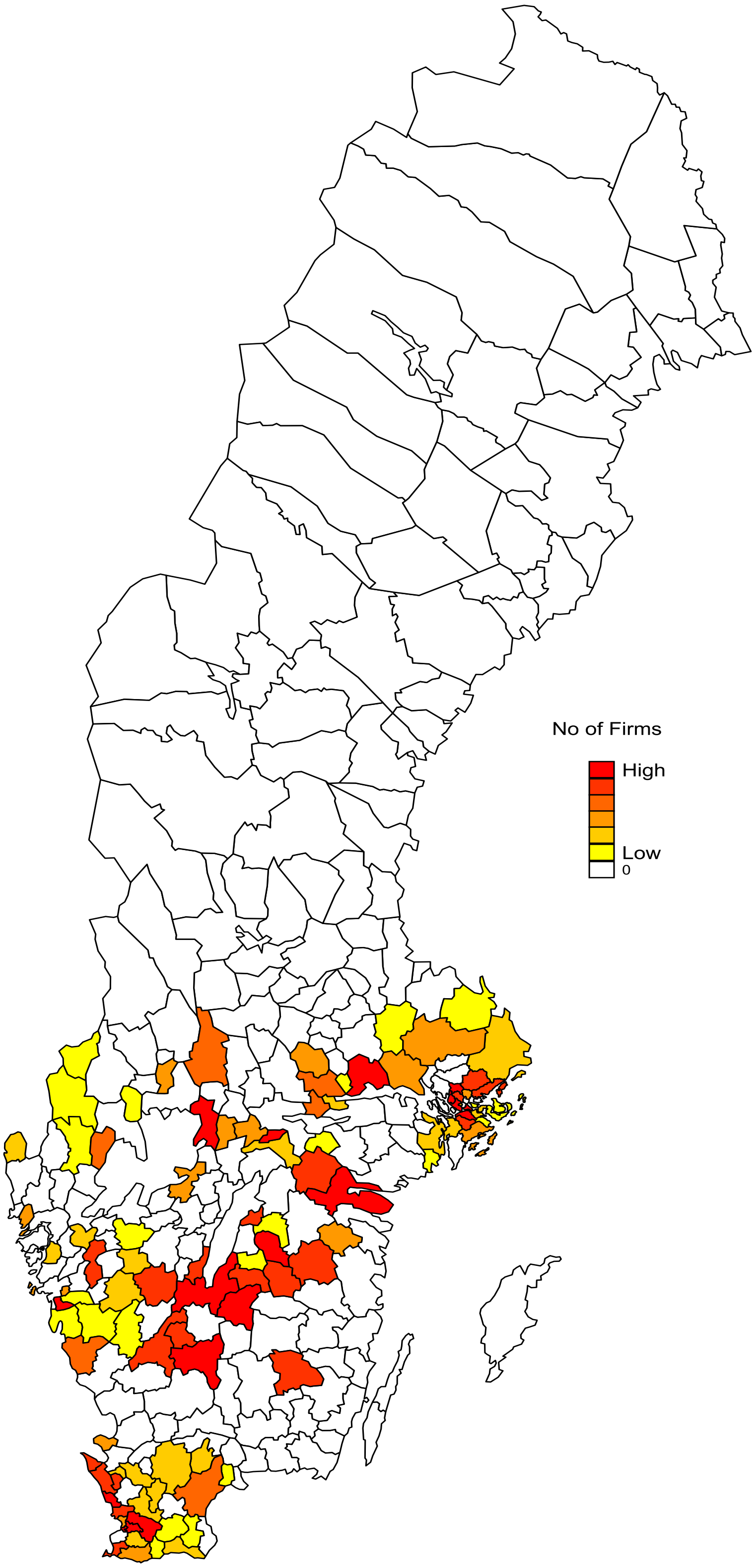
Figure 1 – Appropriability and Absorptive Capacity Trade-offs for Proximate Firms



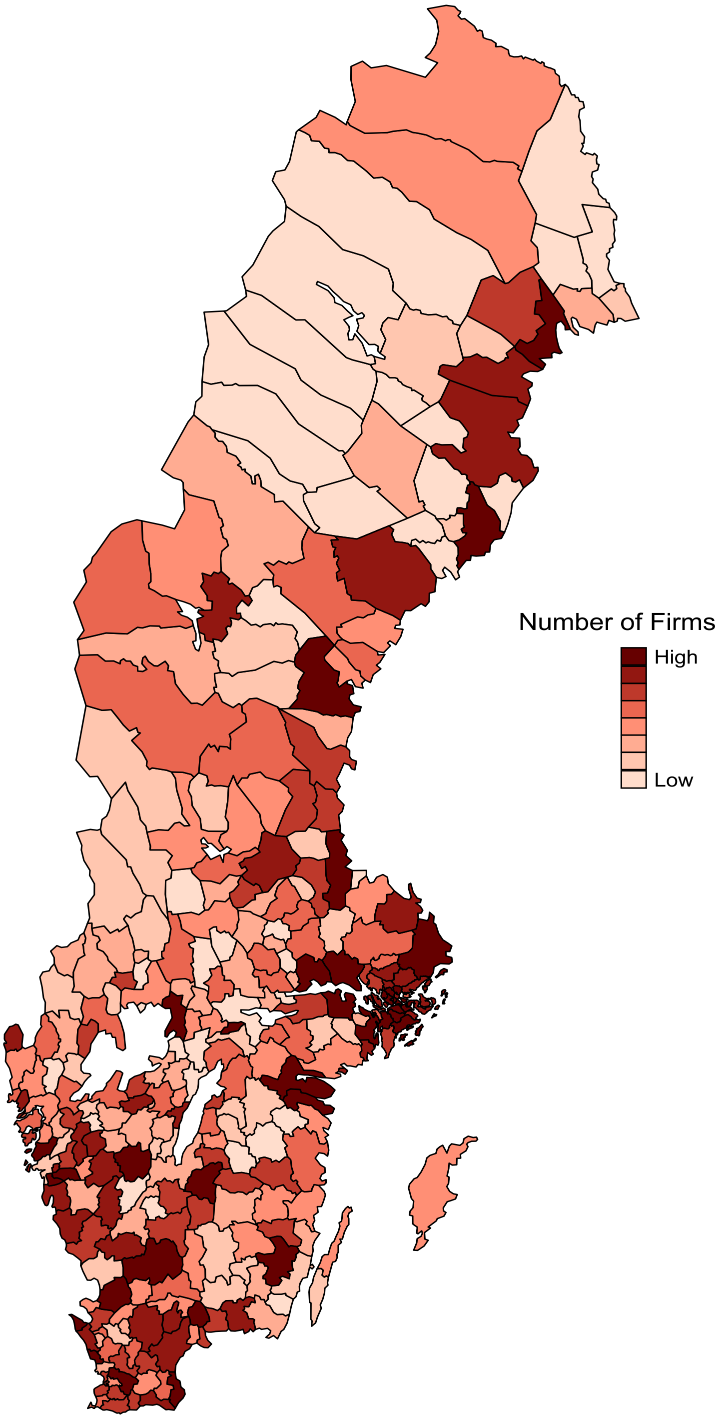
Source: Authors' own

Figure 2 Surveyed firms by location



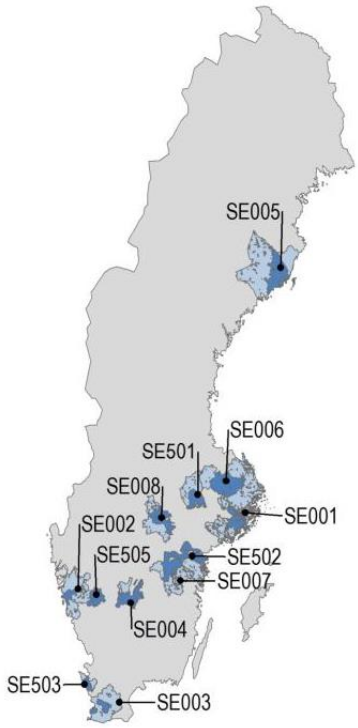
Source: Authors' calculations based on World Bank (2014)

Figure 3 Start-ups by Municipality



Source: Authors' calculations based on Swedish Agency for Growth Policy Analysis (2018)

Figure 4 – Swedish Functional Urban Regions by Commuting Patterns



Source: OECD (2016)

Table 1 Variable Definitions

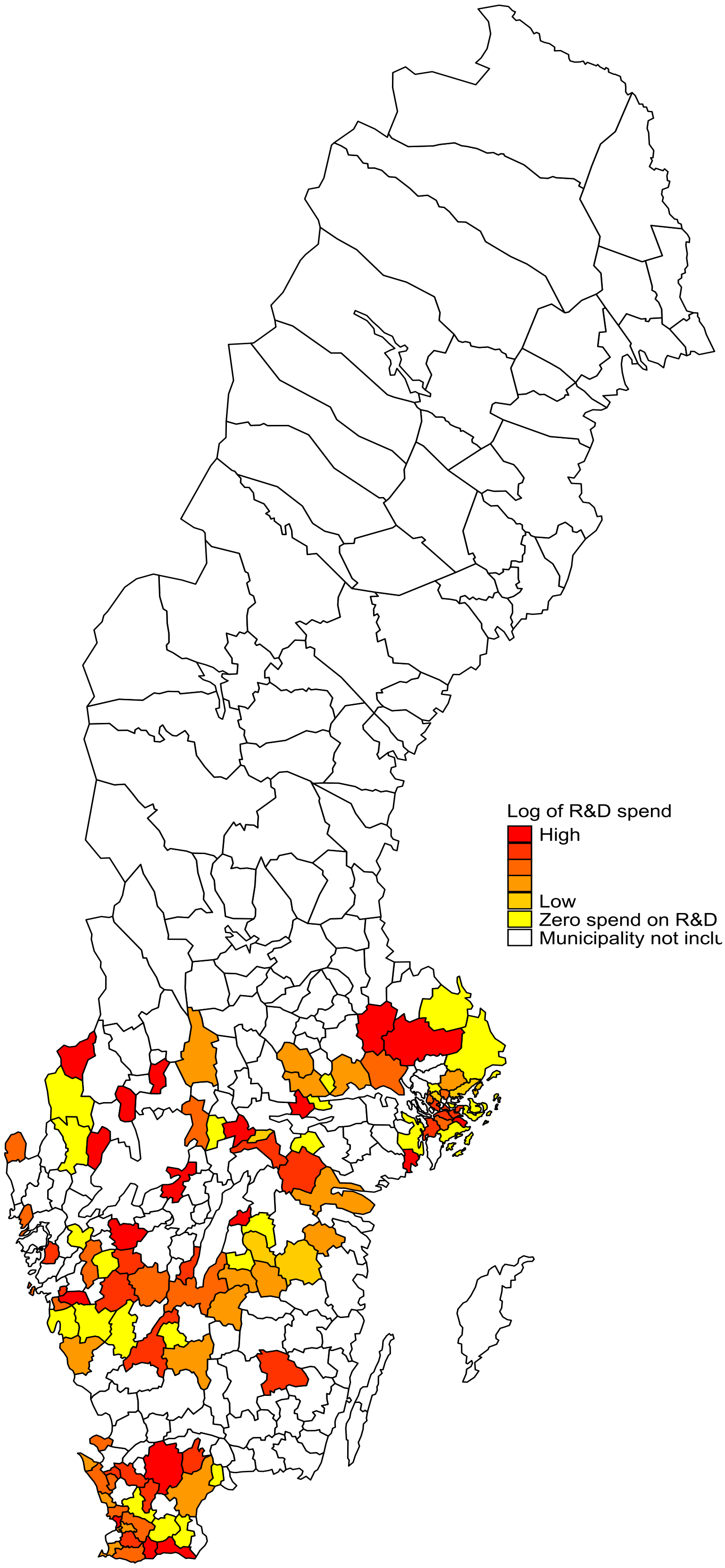
Variable	Description
Log of R&D spend per worker	Log of the cost of research and development activities, either in-house or contracted with other companies in 2030 (in SEK currency)
Log of Firm Start-Ups (Municipalities)	The log of the average number of firm start-ups by municipalities from 2011 to 2013
Log of Age of the Firm	The log of the age of the firm
Employees with Third Level Education (%)	The percentage of employees in the firm with a third level education
Training for Employees	=1 if the firm invests in training for employees, 0 otherwise
Medium to high Knowledge Intensive Industries	=1 if the firm is in the Medium to high knowledge intensive activity category as per Eurostat NACE definition (2013), 0 otherwise
Fabricated Metal	=1 if the firm is in the fabricated metal industry category, 0 otherwise.
Machinery and Equipment	=1 if the firm is in the machinery and equipment category, 0 otherwise
Other Manufacturing	=1 if the firm is in the other manufacturing category, 0 otherwise
Automotive Services	=1 if the firm is in the automotive services category, 0 otherwise
Other Services	=1 if the firm is in the other services category, 0 otherwise
Retail	=1 if the firm is in the retail category, 0 otherwise
Log of Competitors	The log of the absolute number of competitors that the firm has (upper max level at 100)
Foreign Firm	=1 if the firm is a foreign firm, 0 otherwise
Manager Experience	The number of years of experience the top manager of the firm has of working in the sector
Exporting Firm	The percentage of the establishments sales that were directly exported in the past year
Log of Employment	The log of the number of employees in the firm
Finance is an obstacle	=1 if the firm states that getting access to finance is a moderate or major obstacle, 0 otherwise
Stockholm-Solna Region	=1 if the firm is located in Stockholm-Solna Region, 0 otherwise
Boras-Gothenburg-Jonkoping-Trollhattan Region	= 1 if the firm is located in Boras-Gothenburg-Jonkoping-Trollhattan Region, 0 otherwise
Malmo-Lund	=1 if the firm is located in Malmo-Lund, 0 otherwise
Linkoping-Orebro-Karlstad-Vasteras	=1 of the firm is located in Linkoping-Orebro-Karlstad-Vasteras, 0 otherwise

Table 2 Descriptive Statistics

Variable	Mean	Std. Dev.
R&D spend per worker	28810.92	99396.38
Firm Start-Ups (Municipalities/3 year average 2011-13)	989.83	2055.13
Firm Start-Ups (% that are manufacturing at municipal level)	14.94	35.38
Age of the Firm	38.73	34.42
Employees with Third Level Education (%)	10.93	16.67
Training for Employees	70.91	45.46
High Knowledge Intensive Industries	26.18	44.00
Fabricated Metal	20.54	40.44
Machinery and Equipment	20.91	48.84
Other Manufacturing	20.91	34.73
Automotive Services	14.00	34.73
Other Services	13.27	33.95
Retail	11.81	32.31
No of Competitors	4.89	16.18
Foreign Firm	0.22	0.42
Manager Experience	22.66	12.52
Exporting Firm	27.55	34.63
Size of Firm (Employment)	103.54	711.08
Finance is an obstacle	13.64	34.35
Stockholm-Solna Region	18.73	39.05
Boras-Gothenburg-Jonkoping-Trollhattan Region	30.36	46.02
Malmo-Lund	20.36	40.31
Linkoping-Orebro-Karlstad-Vasteras	30.55	46.10

Source: Authors’ calculations based on World Bank (2014)

Figure 5 – Research and Development Spend of surveyed firms by Municipality



Source: Authors' calculations based on World Bank (2014)

Table 3: Results of Estimations

Dependent Variable: Log of R&D spend per worker		
Explanatory Variables	OLS (1)	SAR (2)
Log of Firm Start-Ups (Municipalities)	-2.584**	-2.716***
	(1.058)	(1.048)
Log of Firm Start-Ups Squared (Municipalities)	0.171**	0.179**
	(0.085)	(0.084)
Percentage of Manufacturing Firm Start-Ups	-0.137**	-0.135**
	(0.061)	(0.059)
Log of Age of the Firm	0.278	0.292
	(0.282)	(0.276)
Employees with Third Level Education (%)	0.072***	0.072***
	(0.017)	(0.016)
Training for Employees	1.045*	1.042*
	(0.066)	(0.557)
High Knowledge Intensive Industries	2.323***	2.319***
	(0.885)	(0.868)
Log of Competitors	0.017	-0.011
	(0.288)	(0.278)
Foreign Firm	-0.666	-0.698
	(0.667)	(0.659)
Manager Experience	-0.04*	-0.033
	(0.021)	(0.021)
Exporting Firm	0.060***	0.060***
	(0.010)	(0.010)
Log of Employment	-0.764***	-0.724***
	(0.227)	(0.226)
Finance is an obstacle	0.505	0.485
	(0.772)	(0.759)
Stockholm-Solna Region	0.031	-0.558
	(0.747)	(-0.687)
Boras-Gothenburg-Jonkoping-Trollhattan Region	0.376	0.082
	(0.663)	(0.607)
Malmo-Lund	0.647	0.507
	(0.699)	(0.682)
_cons	9.867***	6.392**
	(3.649)	(2.980)
W		
lognfirms		0.329
		(0.279)
logrdspendpw		-0.366*
		(0.195)
e.logrdspendpw		0.286
		(0.284)
Observations	550	550
Adjusted R2 (OLS)/ Pseudo R2 (SAR)	35.41	31.23
Moran test for spatial dependence (Prob > chi2)	0.6519	
Wald test of spatial terms (Prob > chi2)		0.30.36

Notes: Heteroskedasticity-consistent standard errors are in parentheses. *denotes statistical significance at the 10% level. ** at the 5% level, and *** at the 1% level. The prefix W indicates spatial lag of the corresponding variable. The reference categories are retail and Linkoping-Orebro-Karlstad-Vasteras Region. Sectoral Variables were included but excluded from tables as they were insignificant.

Table 4: Moran's I for Selected Variables

Variable	Moran's I	E(I)	SE(I)	Z(I)	p-value
R&D spend per worker	0.01312	-0.00182	0.03564	0.41934	0.67497
Firm Start-Ups (Municipalities/3 year average 2011-13)	0.81701	-0.00182	0.03561	22.9933	0

Table 5: Average Direct, Indirect and Total Effects

Dependent Variable: Log of R&D spend per worker			
Explanatory Variables	Direct	Indirect	Total
Log of Firm Start-Ups (Municipalities)	-2.729***	0.085	-2.643***
	(1.051)	(0.059)	(1.019)
Log of Firm Start-Ups Squared (Municipalities)	0.179**	-0.004	0.176**
	(0.084)	(0.003)	(0.082)
Percentage of Manufacturing Firm Start-Ups	-0.135**	0.003156	-0.132**
	(0.059)	(0.002)	(0.058)
Log of Age of the Firm	0.291	-0.006	0.284
	(0.276)	(0.007)	(0.284)
Employees with Third Level Education (%)	0.072***	-0.002	0.071***
	(0.016)	(0.001)	(0.016)
Training for Employees	1.043*	-0.024	1.019*
	(0.558)	(0.019)	(0.545)
High Knowledge Intensive Industries	2.324***	-0.054	2.270***
	(0.871)	(0.036)	(0.851)
Log of Competitors	-0.010	0.000	-0.009
	(0.278)	(0.006)	(0.272)
Foreign Firm	-0.701	0.016263	-0.684
	(0.661)	(0.017)	(0.646)
Manager Experience	-0.033	0.000763	-0.032
	(0.021)	(0.000)	(0.020)
Exporting Firm	0.056***	-0.001*	0.055***
	(0.010)	(0.000)	(0.010)
Log of Employment	-0.735***	0.017	-0.718***
	(0.232)	(0.011)	(0.228)
Finance is an obstacle	0.566	-0.013	0.553
	(0.760)	(0.018)	(0.743)
Stockholm-Solna Region	-0.028	0.001	-0.028
	(0.733)	(0.017)	(0.716)
Boras-Gothenburg-Jonkoping-Trollhattan Region	0.393	-0.009	0.384
	(0.652)	(0.016)	(0.636)
Malmo-Lund	0.702	-0.016	0.685
	(0.692)	-0.018	(0.677)