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Kent Eliasson, Pär Hansson and Markus Lindvert

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Kent Eliasson*, Pär Hansson** and Markus Lindvert***

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Abstract

In the paper, we break down business sector R&D at an appropriate regional level (functional analysis regions, FA-regions) in Sweden. We describe the variation and development at the regional level. In an econometric analysis, we examine what affects the location and size of enterprise groups' R&D activities in different FA-regions. We find that enterprise groups concentrate their R&D to the same regions, which are also regions with significant academic R&D (*external agglomeration*). Moreover, colocation of R&D and manufacturing within an enterprise group in a region (*internal agglomeration*) appears to be a significant location factor. Last but not least, the local availability of qualified R&D labor is another important localization factor for business sector R&D. Finally, when we compare the results from the econometric analysis with what enterprise groups themselves states as important motives for location, we find that they match quite well.

Keywords: business sector R&D, regional location, external agglomeration, colocation of R&D and production, abundance of qualified labor

JEL: O32, R11, R12, J24

* Swedish Agency for Growth Policy Analysis, Studentplan 3, SE-831 40 Östersund
and Department of Economics, Umeå University, SE-901 87 Umeå
kent.eliasson@tillvaxtanalys.se

** Swedish Agency for Growth Policy Analysis, Box 574, SE-101 31 Stockholm
and Örebro University School of Business, SE-701 82 Örebro
par.hansson@oru.se

*** Swedish Agency for Growth Policy Analysis, Studentplan 3, SE-831 40 Östersund
markus.lindvert@tillvaxtanalys.se

1. Introduction

For a long time, there has been considerable interest in where business sector research and development (R&D) is located and which factors drive location. R&D is expected to increase access to new knowledge, promote growth and create high-skilled, well-paid jobs. For policy-makers, it is important to know what makes the business sector locate its R&D in a certain country or region.

Among the business groups and firms that report R&D in Sweden, a substantial part of the expenses for R&D is concentrated in a few multinational enterprise groups. The majority of the R&D investments made in the business sector also take place in a few industries. This paper describes the industry composition of R&D in the business sector in Sweden and how it has developed over time.[1]

However, the focus of the paper is on the regional perspective. We break down business sector R&D at an appropriate regional level, namely, functional analysis regions (FA regions).[2] We argue that many previous studies have been carried out at an overly aggregated level, e.g., NUTS2. A weakness of NUTS2 regions compared to FA-regions is that they are markedly larger and thus more heterogeneous.[3] It turns out that the variations in R&D expenditure among different regions in Sweden are very large and that only a handful of densely populated FA-regions with a high proportion of highly educated people account for the absolute majority of business sector R&D.

Eliasson et al. (2020) observes that the geographic mobility of the highly educated population has reinforced the uneven distribution of human capital endowments among FA-regions. The metropolitan regions receive large net inflows of young, highly educated people, while medium-sized and smaller regions show significant

[1] Sweden is an interesting country to study because the business sector R&D expenditure as a share of GDP is, and has been over a long period of time, among the highest in the world. In 2021, the share in Sweden is 2.5 percent, while it is 2.0 percent in OECD and 1.4 percent in EU27. As a share of total R&D expenditure in Sweden, the business sector R&D is high (72 percent in 2021).
[2] Section 3.2 describes in more detail how the FA-regions are constructed.
[3] Sweden consists of eight NUTS2 regions: Stockholm, East Middle Sweden, Småland with the islands, Southern Sweden, Western Sweden, North Middle Sweden, Middle Norrland, and Upper Norrland. This can be compared to the 60 FA-regions we use in this study.

outmigration. Has this meant that, in recent times, there has been an increased concentration of R&D in the business sector in fewer regions?

In addition to describing the regional location of business sector R&D, a main question is to econometrically analyze what affects location and the size of enterprise groups' R&D activities in different FA-regions in Sweden. For this purpose, we make use of panel data on R&D expenditure at a regional level in enterprise groups active in the Swedish business sector between 2001 and 2019.

Spatial proximity and opportunities for face-to-face meetings are assumed to be particularly important when transferring knowledge between individuals and companies. This applies not least when knowledge cannot be codified (Storper and Venables 2004). In the paper, we study whether enterprise groups tend to locate their R&D within the same region as other enterprise groups conduct their R&D or where universities and colleges have extensive R&D activities. In that case, it would be an indication that there is a potential for, and that there actually occur, knowledge transfers among enterprise groups or between academia and enterprise groups (*external agglomeration*) within regions, which would thus be an explanation for enterprise groups' location of R&D.

We also examine to what extent enterprise groups colocate their R&D and manufacturing within the same region, i.e., whether there are reasons for an enterprise group to locate these parts of the value chain close to each other (*internal agglomeration*). Such a need arises if there is knowledge and experience that is difficult to transfer between these operations unless there are frequent face-to-face meetings. In addition, we also study the importance of the availability of qualified R&D personnel in a region for the location of business groups' R&D activities in the region.

An asset in this study is our access to register data at the plant level on the employee occupations, as well as on their level and orientation of education. This allows us to examine to what extent an enterprise group carries out manufacturing and R&D within the same region (*colocation*). Moreover, it helps us to allocate R&D expenses to various FA-regions. With such data on education and occupations, we can also create measures of the availability of potential R&D labor at the regional level.

Another asset is data on universities' and colleges' expenditures on R&D, in total and in science and technology, at the regional level. This means that we can examine the importance of academic R&D activities in a region for the location of business sector R&D in the same region and thus indicate whether there are transfers of knowledge between universities and colleges and the business sector. Universities and colleges in a region, especially if they have extensive R&D activities and postgraduate studies, can also contribute to the supply of skilled labor for enterprise groups with R&D activities in the region; these are, above all, civil engineers and postgraduates with an appropriate subject orientation (potential R&D employees).[4]

In the econometric analysis, we examine whether enterprise groups' R&D expenditures at the regional level increase/decrease over time, i.e., whether there is expansion or contraction of R&D activities (*intensive margin*). In the analysis, we also include observations for enterprise groups' R&D expenditures if an enterprise group has employees in a region but no R&D expenditures (potential R&D regions), marked as zero. This means that we can also capture new establishments of R&D activities in a region but also closures (*extensive margin*). The dependent variable in our econometric model, R&D expenditures by enterprise groups at the regional level over time, is skewed by many zero observations. A convenient way to handle this is to estimate the model with Poisson pseudo maximum likelihood (PPML).[5]

[4] In a survey of 200 R&D-intensive companies reported in IVA (2022), the R&D managers answer that the most important factor for their R&D activities is the availability of competence. They also believe that it has become increasingly difficult to recruit personnel for R&D. A possible explanation for this skills shortage, highlighted by Deming and Noray (2020), is that the professions that are relevant for this activity, STEM professions, i.e., professions in science, technology, engineering, and mathematics, are characterized by the fact that they are affected by very rapid technological development. This means that those who work in these professions must constantly learn new things, while their old knowledge from their education quickly becomes obsolete. This results in the income premium for degree-holders in these fields falling rapidly and causes them to leave for other professions to a greater extent than those who have their education in other fields.

[5] Section 4.1 discusses the advantages of this approach.

Our approach differs from that used by a number published studies of what determines the location of R&D at the regional level.[6] They use discrete choice models to study in which regions within the EU (NUTS2) or in which global cities multinational enterprises choose to invest in R&D and what characterize these regions/cities.

Andersson and Ejermo (2005) use Swedish data that has a regional perspective, and their study is similar to ours. They examine the impact of accessibility to internal and external sources of knowledge on the innovation capacity of Swedish enterprise groups. Unlike in our study, their dependent variable is the output from the innovation process, namely, patents per enterprise group. One result from their analysis is that the extent of the enterprise group's own research (input in the innovation process) is important for the probability of producing a patent. Another is that an enterprise group's innovation capacity is positively related to how accessible university research is within the regions where the enterprise group's own research units are located.

The results from our econometric analysis of the location of R&D expenditure at the regional level among enterprise groups active in Sweden show – partial correlations – that enterprise groups tend to conduct their R&D in the same places, which is also where there are universities and colleges with significant R&D activities (*external agglomeration*). Hence, there seems to be knowledge transfers among enterprise groups and between universities and enterprise groups within the same region. Moreover, the local availability of potential R&D employees appears to play an important role in where businesses locate their R&D activities. We also find that the colocation of R&D and manufacturing within an enterprise group in a region (*internal agglomeration*) seems to be another significant location factor.[7]

In the paper, we also compare our econometric results with what the enterprise groups themselves state as important motives when they decide where to locate

[6] See, e.g., Siedschlag et al. (2013), Crescenzi et al. (2014) and Castellani and Lavaratori (2018).
[7] Several large enterprise groups within manufacturing with substantial R&D activities in Sweden tend to also colocate R&D and manufacturing in their subsidiaries abroad (Ivarsson et al. 2017).

their R&D activities. We present the results from a survey among the 20 Swedish multinational enterprises that have the largest R&D expenditures about their underlying motives for locating their R&D to a certain country (Sweden included). We find that the results from the econometric analysis and what the enterprise groups state in the survey matches quite well. Overall, this strengthens our conclusions about which factors that are important for the regional location of business sector R&D.

The paper is structured as follows. Section 2 discusses, based on the previous literature, what can be expected to determine the location of R&D regionally. Section 3 presents the data and describes how R&D expenditure has developed within the Swedish business sector at both the industry and regional levels. Section 4.1 describes how the econometric analysis is carried out and Section 4.2 presents the results. In Section 4.3, we compare our econometric results on location factors with the survey among the Swedish multinational enterprises about driving forces for location of R&D activities. Finally, Section 5 summarizes the main conclusions and discusses what lessons can be drawn from the study.

2. What determines the location of R&D at the regional level?

From the literature, we can identify three important drivers of enterprise groups' choice of location for its R&D in a region: (i) potential for knowledge transfer from R&D carried out by other enterprise groups and universities or colleges in the same region (*external agglomeration*), (ii) advantages of the colocation of activities along the value chain in the same region, for example, R&D and manufacturing (*internal agglomeration*), and (iii) abundant supply of qualified labor.

The importance of agglomeration economies as a driving force for location was already noted by Marshall (1920). He argued that companies located within a geographically limited area could benefit by gaining access to a larger pool of specialized labor and suppliers and that proximity would facilitate knowledge transfer between adjacent companies and functions within an enterprise group. Certain types of knowledge can be difficult to communicate; they are implicit and cannot be codified (*tacit knowledge*). Such knowledge is difficult to pass on, but the transfer is favored by proximity.[8]

To take advantage of the positive opportunities that arise, as knowledge transfer, enterprise groups usually locate their own R&D in the vicinity of other enterprise groups' R&D in a given region (Alcácer and Chung 2007).[9] One channel for knowledge transfer is when employees move between enterprises and thus bring the knowledge with them to the new employer.[10] Proximity between enterprise groups, especially if they are located in the same FA-region, should facilitate labor mobility between them.[11]

Basic research is mainly carried out at universities and colleges, while business sector R&D is more focused on development and applied research. In many areas, these activities are complementary, and the potential knowledge transfer from academia to enterprises means that enterprise groups in the business sector have an interest in locating their R&D activities in the neighborhood of (in the same region as) universities and colleges with significant research activities, especially if they are of high quality.[12]

[8] Others who have pointed to the economic benefits that densely populated environments, such as large cities, give rise to (positive agglomeration effects) are Duranton and Puga (2004). They distinguish three mechanisms: sharing, matching and learning. Big cities provide a more varied range of qualified services because there are many companies there that demand such services (sharing). In large cities, the probability increases, especially for qualified workers, of finding a job that corresponds to their special skills (matching). Greater proximity between individuals and companies facilitates the spread of knowledge between them (learning). Agglomeration favors experimentation and learning and enables individuals and companies to gain valuable experience. Recent findings in De la Roca and Puga (2017) and Eliasson and Westerlund (2023) show that human capital accumulation and learning effects are the main mechanisms behind dynamic agglomeration effects in big cities.

[9] However, new research points to the fact that technological development can contribute to reducing the importance of physical proximity for knowledge transfer and innovative activities. This applies to both the development of physical infrastructure (Dong et al. 2020) and improved IT infrastructure (Chen et al. 2022, Pearce 2023). However, in a longer historical perspective, improved transport and telecommunications have contributed most directly to increasing the geographical concentration of economic activity (Leamer and Storper 2001). Florida et al. (2023) argue that, as improved transport and telecommunications contribute to more routine activities being spread out geographically, we develop even more new, high-tech activities that benefit from physical proximity.

[10] Balsvik (2011) and Poole (2013) are two studies that analyze knowledge spillovers between companies as a result of employees moving from multinational enterprises to domestic firms.

[11]. However, the benefit an enterprise has from locating close to other companies varies. Technologically leading corporations probably have less incentive, due to the risk of significant knowledge leakage, to be located where less advanced competitors are congregated (Shaver and Flyer 2000).

[12] See, e.g., Abramovsky et al. (2007). They examine the relationship between the location of business sector R&D and academic research institutions in the UK, and they find strong evidence for colocation between academia and business in regard to pharmaceutical research. García-Vega and Vicente-Chirivella (2020) find

Internal agglomeration, particularly the colocation of R&D and manufacturing, has attracted substantial interest in the literature. The mechanisms through which internal agglomeration could lead to improved results are: (i) better coordination, control and overview, (ii) facilitating communication and knowledge sharing, and (iii) increased economies of scale and scope in the internal labor market (Alcácer and Delgado 2016). The latter can be achieved because colocation within the same region makes it easier to coordinate and allocate the workforce.

The existence of strong internal links within an enterprise between R&D and manufacturing could justify placing such activities close to each other. Usually, enterprise groups decide to establish new R&D operations in regions where they already have manufacturing. The proximity between a newly established R&D activity and the already existing manufacturing facilitates local knowledge transfer, where the R&D specialists can learn from the experience of production experts and vice versa.

Colocation is particularly important when extensive communication between functions is needed, non-standardized information needs to be shared, tacit knowledge needs to be transferred, and common production problems require solutions. Furthermore, the need for physical colocation of R&D and manufacturing appears to be greater as the products and production processes grow more complex; the less mature the production processes are, the less functionally distinct units are used, i.e., the lower the degree of modularity (Ketokivi and Ali-Yrkko 2009).

A broad knowledge base and availability of qualified R&D personnel are factors that have often been pointed out in previous empirical studies as significant for the location of R&D.[13] These are also the factors usually ranked highest in surveys among R&D-intensive companies of the main driving forces for R&D locations

that technology transfer from universities generates positive knowledge spillovers to enterprises, strengthening their internal R&D capability.

[13] See, e.g., OECD (2008), Athukorala and Kohpaiboon (2010) and Siedschlag et al. (2013).

selection.[14] In other words, the ability of a region to supply the type of human capital required to establish R&D activities appears to be one of the most important location factors. Universities and colleges that carry out extensive research activities, especially in sciences and technology, provide, in addition to basic and applied research, competent research-trained R&D personnel, not least to the region where they are located.

3. Business sector R&D in Sweden

The empirical analysis is mainly based on data on R&D expenditure at the enterprise group level. Such data are collected by Statistics Sweden (SCB) using a survey repeated every two years at the firm level, which we then aggregate to the enterprise group level. We use data from 2001 to 2019.[15] In addition, we use data from Statistics Sweden's regional labor market statistics and the occupational and educational registers.

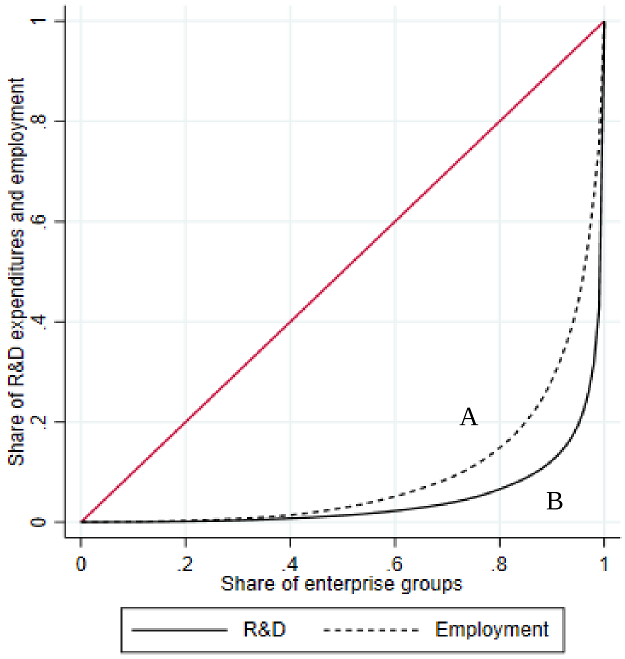
3.1 R&D at the enterprise group and industry levels

It turns out that the business sector R&D expenditure in Sweden is heavily concentrated in a few enterprise groups. This can be seen in Figure 1, where we plotted a Lorenz curve that describes the distribution of R&D between the enterprise groups included in Statistics Sweden's (SCB’s) regular survey in 2019. As a comparison, the figure also shows the distribution of employment among the same enterprise groups.

[14] See Thursby and Thursby (2006). They asked over 200 multinational companies in 15 countries about the factors that influence their decisions to locate their R&D activities.

[15] The R&D survey of the business sector in 2019 is a combined total and sample survey. The total survey includes firms with more than 199 employees, firms that in the previous sampling year had R&D expenses that exceeded SEK 5 million and have more than nine employees, firms that are industrial research institutes regardless of employees, and firms in the industry scientific research and development (ISIC 72) with more than nine employees. Firms that do not meet the selection criteria are investigated through probability sampling.

Figure 1 Concentration of R&D expenditure and employment in enterprise groups carrying out R&D



Source: SCB and Growth Analysis Individual and Firm Database (IFDB)

In 2019, one percent of the enterprise groups with the largest R&D expenditures (just over six groups) carried out 57 percent of the total R&D expenditures in the survey. Figure 1 shows that employment is also skewed among the enterprise groups, although not nearly as skewed as for R&D expenditure. In regard to employment, one percent of the enterprise groups with the most employees account for 25 percent of the total employment in the enterprise groups in the survey.[16] It should be noted that enterprise groups that make investments in R&D, especially those that have the largest R&D expenditures, tend to be relatively large. In the 2019 survey, the average number of employees in the enterprise groups was 1,178, the median was 186 employees, and in total, 651 enterprise groups were included in the survey.

[16] Figure 1 can also be seen as a graphical representation of the Gini coefficients for R&D and employment, where the Gini coefficient is A/(A+B). A is the area between the Lorenz curve and the 45-degree line and B is the area on the outside of the Lorenz curve. The Gini coefficient for R&D is 0.91. The Gini coefficient for employment is 0.81, and as expected, lower than for R&D.

The absolute majority of the enterprise groups that carry out R&D activities in Sweden are multinational enterprises (MNEs), Swedish- or foreign-owned; in 2019, Swedish MNEs conducted 50 percent of R&D, foreign-owned MNEs conducted 43 percent and the remaining 7 percent were accounted for by national companies.

A few industries contribute to the bulk of the R&D investments carried out in the Swedish business sector. Table 1 shows in which industries/sectors we find the largest R&D expenditures in 2021 and where the largest changes occurred between 2009 and 2021.

Table 1 R&D expenditures at the industry level in 2021 and 2009, billions of SEK and 2019 prices

ISIC	Industry/sector	2021		2009		Change	
		billion	share	billion	share	billion	share
29+30	Transport equipment	31.2	24.9	18.1	19.2	13.0	5.7
58–63	Information and communication	29.0	23.2	5,4	5,7	23,6	17,5
72	Research and development	13.4	10.7	11.7	12.3	1.7	-1.6
28	Other machinery	10.1	8.1	6.7	7.0	3.5	1.1
21	Pharmaceuticals	9.4	7.5	7.4	7.9	2.0	-0.4
*	Wholesale and retail trade, hotels and restaurants	7.0	5.6	2.7	2.8	4.3	2.8
26	Computer, electronic and optical products	3.7	2.9	21.9	23.1	-18.2	-20.2
25	Fabricated metal products	3.0	2.4	2.2	2.3	0.8	0.1
64–66	Financial service and insurance	2.9	2.4	0.7	0.8	2.2	1.6
27	Electrical equipment	2.9	2.3	2.7	2.8	0.2	-0.5
**	Advertising and other business services	2.3	1.8	1.7	1.8	0.6	0.0
71	Architectural and engineering activities, technical testing	2.2	1.8	1.3	1.3	0.9	0.5
17	Paper and pulp	1.5	1.2	3.8	4.0	-2.3	-2.8
19–20	Coke, petroleum products and chemicals	1.4	1.1	2.2	2.3	-0.8	-1.2
	Other industries	5.1	4.1	6.2	6.6	-1.1	-2.5
	Total	125.2	100.0	94.7	100.0	30.5	

Notes: *ISIC 45–47+55–56 and **73–75+82+84–99. Shares in percent.

Source: SCB, Research and development in Sweden – the business sector

According to Table 1, it is the sectors of *transport equipment* and *information and communication* that, in 2021, carried out the most R&D. Each of these accounts for almost a quarter of the R&D investments, which means that almost half of all R&D expenditure in the Swedish business sector is conducted in these two sectors. Transport equipment is dominated by the *motor vehicles* industry, and in *information and communication*, the *computer programming and computer consulting* industry is particularly prominent in R&D expenditure.[17] The increase in R&D expenditure in *transport equipment* is 13 billion SEK in absolute terms, and the sector's share of total R&D investments in the business sector grew by almost 6 percentage points between 2009 and 2021. This is mainly a consequence of higher R&D expenditure in the *motor vehicles* industry.[18]

The sharp increase in R&D expenditure in the *information and communication* sector, which we observe in Table 1, is to a large extent a result of the very R&D-intensive telecom company Ericsson being reclassified in 2015 from the *computer, electronic and optical products* industry to the *computer programming and computer consulting* industry. Notably, however, if we exclude Ericsson from *computer programming and computer consulting* from 2015 onwards, we can still observe a significant increase in R&D investments in that industry during the study period.[19] It thus appears as if, in recent times, there has been a general increase in the investment in R&D within *computer programming and computer consulting*.

Significant R&D efforts can also be observed in the following industries: *research and development*, *other machinery*, and *pharmaceuticals*. We notice remarkable increases in the shares of total business sector R&D expenditure in the sectors of *financial services and insurance* and *wholesale and retail trade, hotels and restaurants*; in the latter, the *wholesale trade* industry is the most prominent. We

[17] In 2019, 80 percent of the R&D expenditure in the sector *transport equipment* belongs to the industry *motor vehicles* and in the sector *information and communication*, the share of the industry *computer programming and computer consulting* is even higher.
[18] Between 2009 and 2019, investments in R&D in the industry *motor vehicles* increased by 5.5 billion SEK in constant prices, while the R&D expenditure in the industry *other transport equipment* grew by 1.5 billion.
[19] Unfortunately, due to confidentiality reasons, we cannot report the figures that substantiate this claim.

find reduced R&D investments, both in absolute and relative terms, in the *paper and pulp* industry.

3.2 Regional distribution of the business sector R&D

In Figure 1, we noted that R&D expenditure is heavily concentrated in a few enterprise groups in the business sector. In addition, R&D spending is also highly concentrated in a few regions.

Before going into this, it should be mentioned that the analysis of the location of R&D at the regional level is carried out on functional analysis regions (FA-regions). We want to work with regions that are economically integrated to the greatest extent possible, i.e., regions where the residents both live and work, which is the basic idea behind the creation of the FA-regions. In that respect, the FA-regions differ from counties and municipalities, which are purely administrative units, even though municipalities are the building blocks of the FA-regions.[20]

Regarding the R&D expenditure at the enterprise group level, these are only broken down at the county level, but in most cases, this does not pose a problem, as it is usually possible to attribute the enterprise group's R&D to a certain municipality within the county and thus to the FA-region. However, difficulties arise if an enterprise group has operations (plants) in several municipalities within a county and that also belong to different FA-regions. To be able, in these cases, to distribute the R&D expenses at the municipal level, we calculate the proportion of people working in "R&D occupations" at the plants concerned. Occupational groups defined as "R&D occupations" are where a longer university education[21] with a focus on science and technology or IT is normally needed, and we identified two occupational groups as "R&D occupations".[22]

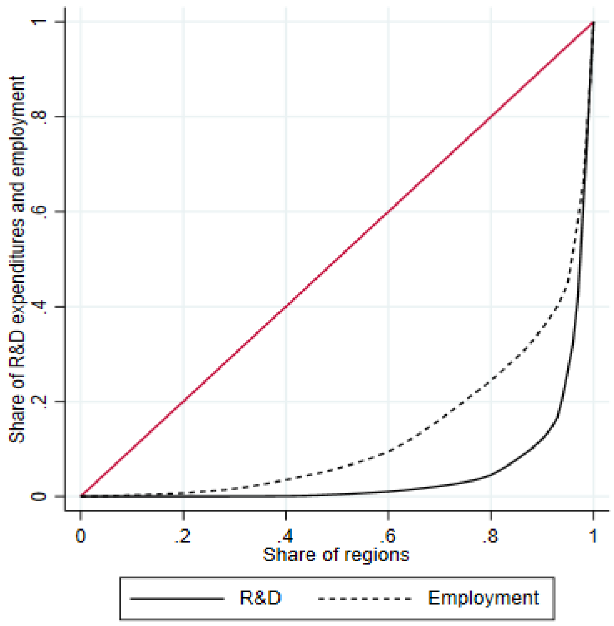
[20] Commuting patterns between Sweden's 290 municipalities are used to determine what the FA-regions should look like. These are constructed by merging municipalities so that commuting flows between FA-regions are minimized. Growth Analysis (2015) contains a more detailed description of how the FA-regions have been created.

[21] Postsecondary education that requires at least 3 years and normally 4 years or longer.

[22] SSYK 21 and SSYK 25. Standard for Swedish occupational classification (SSYK) is the system that Statistics Sweden uses to group individuals' occupations or tasks. The number 2 indicates that it is a longer university education. 21 is oriented toward science and technology and 25 toward IT. In enterprise groups with considerable R&D expenditures, these are two occupational categories that are particularly well represented.

Access to data on enterprise groups' R&D expenditure at the FA-regional level – later also used as the dependent variable in the econometric analysis – allows us to aggregate these to describe the regional structure of business sector R&D. Figure 2 compares the concentration of R&D expenditure with employment in the 60 Swedish FA-regions in 2019 using Lorenz curves.

Figure 2 Regional concentration of R&D and employment among FA-regions



Source: SCB and Growth Analysis Individual and Firm Database (IFDB)

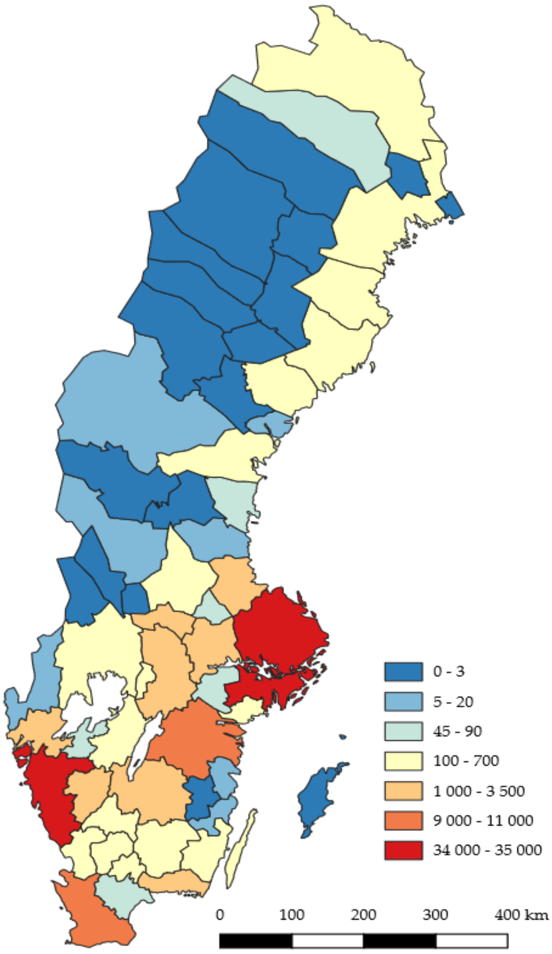
In 2019, 88 percent of all R&D expenditure in the business sector was carried out in 10 percent of the total number of FA-regions (the six regions with the largest R&D expenditures). When we contrast this with employment in the business sector, we can see that employment is clearly less concentrated; the six regions with the most employees have 65 percent of employment in the business sector. If we compare the Gini coefficients for R&D and for employment in 2019, these also verify that R&D spending is more concentrated; the Gini coefficient for R&D is 0.90, while it is 0.70 for employment.

Eliasson et al. (2020) shows that highly educated population has had a tendency to move from medium-sized and smaller regions to metropolitan regions. Therefore, one would perhaps expect that there has been an increased concentration of R&D

in the business sector in the larger regions over time. However, this does not seem to be the case because when we calculate the Gini coefficients for R&D in 2019 and 2001, they are the same for both years (0.90).

A more detailed picture of the regional location of R&D expenditure in the business sector is given in Figure 3 and Table 2. Figure 3 illustrates the variation in R&D expenditure among the Swedish FA-regions in 2019, and Table 2 shows some trends that can be observed among the five most significant FA-regions in 2019.

Figure 3 R&D expenditure in the business sector in FA-regions, 2019



Notes: R&D expenditure in million SEK

Source: Own calculations based on SCB, Research and development in Sweden – the business sector (survey data)

Figure 3 and Table 2 show that there are two FA-regions that stand out, namely, Stockholm-Uppsala and Göteborg. In these regions, R&D expenditure amounts to approximately 35 billion SEK. Together, these regions hold slightly more than 64 percent of the total R&D expenditure in the business sector. Two more regions with significant R&D investments are Malmö-Lund and Linköping-Norrköping. The R&D expenditure in these regions is approximately 10 billion SEK each, and together, these regions provide almost 19 percent of the business sector R&D investments in Sweden. Table 2 also includes Karlskrona, where R&D expenditure is clearly lower than in the other four regions (3.5 billion SEK and just over 3 percent of total R&D expenditure).

Table 2 R&D expenditures in the five most important FA-regions in 2001 and 2019; 2019 prices, billion SEK

FA-region	R&D 2019		R&D 2001		Difference	
	billion	share	billion	share	billion	share
Stockholm-Uppsala	35.0	32.2	39.1	39.4	-4.1	-7.2
Göteborg	34.7	32.0	27.1	27.4	7.6	4.6
Malmö-Lund	10.2	9.4	10.5	10.6	-0.3	-1.2
Linköping-Norrköping	9.9	9.1	6.4	6.4	3.5	2.7
Karlskrona	3.5	3.2	1.1	1.1	2.4	2.1
Other	15.4	14.1	15.0	15.1	0.4	-1.0
All FA-regions	108.7	100.0	99.2	100.0		
Gini coefficient	0.90		0.90			

Notes: The figures presented above have been aggregated directly from the information provided by the individual enterprise groups in Statistics Sweden’s survey of R&D expenditure in the business sector. In the official figures presented by Statistics Sweden, certain calculations (using sampling weights) are made, which means that the figures above are not directly comparable to Statistics Sweden’s official figures, for example, those shown in Table 1 above.

Source: SCB, Research and development in Sweden – the business sector (survey data)

Furthermore, we can see in Figure 3 that another seven regions, located in southern and central of Sweden, have R&D expenditures greater than one billion.[23] It is noteworthy that no region in northern Sweden has R&D expenditures over 0.5

[23] They are bright orange and the FA-regions are Västerås, Borås, Trollhättan-Vänersborg, Jönköping, Gävle, Örebro, and Ludvika.

billion.[24] Typically, and not particularly surprisingly, the regions with the lowest R&D spending are sparsely populated rural regions.

Table 2 shows that between 2001 and 2019, Göteborg has almost caught up with Stockholm-Uppsala, where instead there has been a marked reduction in R&D investments, even in absolute terms. We also note that investments in R&D in Linköping-Norrköping have increased significantly and are now at roughly the same level as in Malmö-Lund. In the latter region, R&D spending in 2019 was approximately the same as that in 2001. In Karlskrona and the other seven regions with R&D spending greater than one billion (see Figure 3), we observe increases in R&D spending in all regions, with the exception of Trollhättan-Vänersborg.[25] In some of these regions, the increases have been considerable, for example, in Karlskrona and Borås.

In Table 3, we show which industries are the most prominent in terms of R&D investment in the five FA-regions with the largest R&D expenditures (Table 2).

Table 3 Industries with extensive R&D spending in the most significant FA-regions

ISIC	FA-region/industries
	Stockholm-Uppsala
62	Computer programming and computer consulting
29	Motor vehicles
72	Research and development
26	Computer, electronic and optical products
46	Wholesale trade
20	Chemicals and chemical products
	Göteborg
29	Motor vehicles
21	Pharmaceuticals
62	Computer programming and computer consulting
28	Other machinery
	Malmö-Lund
46	Wholesale trade
62	Computer programming and computer consulting

[24] Worth noting in this context is that Northvolt, which has its manufacturing of batteries in Skellefteå, has located its testing and development to Västerås
[25] An explanation is the closure of Saab Automobile in 2011.

ISIC	FA-region/industries
72	Research and development
	Linköping-Norrköping
30	Other transport equipment
62	Computer programming and computer consulting
71	Architectural and engineering activities, technical testing
	Karlskrona
29	Motor vehicles
62	Computer programming and computer consulting

Most R&D in the Stockholm-Uppsala region is carried out in the industry of *computer programming and computer consulting*, while in Göteborg, the largest R&D expenditures are in *motor vehicles*. Heavily increased investments in R&D in the latter industry in the Göteborg region is a strong reason why R&D expenditure in Göteborg is now at approximately the same level as that in Stockholm-Uppsala (Table 2). *Computer programming and computer consulting* and *motor vehicles* are proving to be important industries in other regions as well, such as Malmö-Lund, Linköping-Norrköping and Karlskrona. This is not particularly surprising considering that these industries account for most R&D in the Swedish business sector (Table 1).

Moreover, we observe, in Table 3, that in Linköping-Norrköping, *other transport equipment* is the dominant industry in R&D. *Other machinery* is an important R&D industry in many of the FA-regions, with R&D expenditures greater than one billion but less than 3.5 billion SEK (bright orange in Figure 3). This industry includes a number of large Swedish-owned multinational enterprises. Finally, we find that in the FA-regions where the R&D expenditures are somewhat lower than those presented in Table 3, the R&D investments are often concentrated in a single industry (and enterprise group).[26] In that respect, these differ from Stockholm-Uppsala and Göteborg, where there are a number of industries with significant R&D expenditures.

[26] For confidentiality reasons, we cannot report who they are.

4. Factors explaining the regional location of business sector R&D

4.1 Econometric specification

On the basis of the discussion held in Section 2 about what determines the location of business R&D at the regional level, we specify and estimate a model described by equation (1). The model aims to explain variations in R&D expenditure at the enterprise group level in different FA-regions over time.[27] In that respect, the approach differs from previous studies that are based on a discrete choice model but where similar explanatory variables are used.[28]

Our dependent variable, RD_{irt}, R&D expenditure in constant prices in enterprise group *i* in FA region *r* at time *t*, has a significant number of zero observations (78 percent). This is because we include those for enterprise groups that do not have R&D expenditure in a region at a given time but do, however, have employees in the region.[29] A convenient way to include zero observations in the dependent variable and to deal with heteroscedasticity problems is to estimate the model in equation (1) with Poisson pseudo maximum likelihood (PPML).[30] This estimator has been shown to be robust to many variations of incorrect distributional assumptions and can be used in all kinds of applications where the dependent variable takes nonnegative values (Wooldridge 1999, 2002).[31]

$$RD_{irt} = exp\left[\beta_1 SRD_{nrt-1} + \beta_2 SRD_{(n)rt-1} + \beta_3 SE^{man}_{irt-1} + \beta_4 SRD^{uni}_{rt-1}\right] \times$$
$$exp\left[\beta_5 SE^{r\&d}_{rt-1} + \beta_6 E_{it-1} + \beta_7 GRP_{rt-1} + \gamma_i + \gamma_t\right] \times \varepsilon_{irt} \qquad (1)$$

[27] In the specification of the model, we do not take so-called spatial autocorrelation into account (see for example Anselin et al. 2004). This type of correlation occurs if there are spatial dependencies between the geographic units in the analysis. Since our analysis is based on a functional region division (see p.14, note 20), the purpose of which is to delineate regions with a high degree of internal interactions but a relatively small exchange with surrounding regions, the problem of possible spatial autocorrelation is likely to be significantly less than would have been the case if we had used the municipality as the analytical unit.
[28] See p.6, where some recently published studies on determinants of R&D location at the regional level are discussed.
[29] The reason for this is discussed in more detail below on p. 26.
[30] We follow a procedure that has been adopted in regard to estimating gravity models, where the dependent variable has nonnegative values, is skewed continuously distributed, and has many zero observations. See Santos Silva and Tenreyro (2006, 2022).
[31] For a discussion of the advantages of fixed-effect Poisson over alternative estimators, see also https://www.statalist.org/forums/forum/general-stata-discussion/general/1508561-correcting-standard-errors-for-a-fixed-effects-poisson-model.

The dependent variable, RD_{irt}, is R&D expenditure at constant prices in enterprise group *i* in FA region *r* at time *t*. Note that the explanatory variables in the model are lagged (two years behind in time) in relation to the dependent variable. This is to take into account that the decisions to invest in R&D are made in the period before the expenditure for R&D takes place. Shifting the explanatory variables backward in time is also at least an attempt to avoid prevalent endogeneity problems.

External agglomeration, which arises when other enterprise groups conduct R&D in the same region, as we point out in Section 2, is a factor that could have a positive impact on an enterprise group's willingness to carry out its R&D in that particular region. The potential knowledge transfers from colocation could be of intra- or interindustry nature. Knowledge transfers take place *within* industries if the colocated enterprise groups are active in the same industry and *between* industries if the enterprise groups are active in different industries. The proximity between enterprise groups located in the same FA-region favors labor mobility between these enterprise groups. The variable SRD_{nrt-1} is expected to capture potential knowledge transfers (spillovers) *within* industries, and the variable $SRD_{(n)rt-1}$ captures potential knowledge transfers (spillovers) *between* industries.

RD_{nrt-1} consists of R&D expenses in enterprise groups *j* (other than enterprise group *i*) that belong to the same industry *n* (ISIC 2-digit) and are located in the same region *r* as enterprise group *i*, that is ($j \neq i$) and ($i, j \in n, r$). SRD_{nrt-1} is the share of RD_{nrt-1} from the total R&D expenditure that takes place in all regions in industry *n* except for in enterprise group *i*. If we assume that enterprise group *i* is active in the automotive industry *n*; then RD_{nrt-1} is the sum of all R&D expenditures made in the automotive industry in region *r* at time *t-1* except for enterprise group *i*'s R&D expenditures in region *r*. SRD_{nrt-1} is the share of RD_{nrt-1} from all R&D expenditure in the automotive industry in Sweden, apart from enterprise group *i*'s.

$RD_{(n)rt-1}$ consists of R&D expenses in enterprise groups *j* (other than enterprise group *i*) that belong to industries other than *n* and are located in the same region *r* as enterprise group i, i.e., ($j \neq i$), ($j \notin n$), and ($i, j \in r$). $SRD_{(n)rt-1}$ is the share of $RD_{(n)rt-1}$ from the total R&D expenditure that takes place outside industry n in all regions. If enterprise group i belongs to the automotive industry n, then $RD_{(n)rt-1}$ are all R&D expenditures made in region r outside the automotive industry at time t-1. $SRD_{(n)rt-1}$ is the share of $RD_{(n)rt-1}$ in all R&D expenditures made outside the automotive industry in Sweden.

For both of these variables, which in both cases aim to measure opportunities for knowledge transfers (spillovers), the larger the shares SRD_{nrt-1} and $SRD_{(n)rt-1}$ are, the more attracted enterprise group i is to invest in R&D in region r at time t.

Another factor highlighted in Section 2 that could lead an enterprise group to locate its R&D in a certain region is internal agglomeration. Incentives for internal agglomeration arise if geographical proximity between certain operations within an enterprise group manifests in improved productivity. More specifically, it is usually claimed that colocation between R&D and manufacturing may facilitate the mutual exchange of knowledge between these activities. This is especially true when a large part of the knowledge is implicit. If this is the case, there are strong drivers for the colocation of R&D and manufacturing to the same FA-region.

To examine the extent to which the colocation of R&D and manufacturing is significant, we introduce the variable SE_{irt-1}^{man} in equation (1). E_{irt-1}^{man} is the number of employees in manufacturing occupations (m occupations) that enterprise group i has in region r at time t-1.[32] SE_{irt-1}^{man} is the proportion of employees in m occupations that enterprise group i has in region r of the total number of employees in m occupations in enterprise group i. If the proportion of employees in m occupations in an enterprise group in a region is positively related to the R&D

[32] For m occupations, we use the Standard for Swedish occupational classification (SSYK): 71–74, 81–83, and 93. These are production worker occupational groups that occur abundantly among companies in the manufacturing industry. SSYK 71 are building and related trades workers, 72 metal, machinery and related trades workers, 73 handicraft and printing workers, 74 electrical and electronics trades workers, 81 stationary plants and machinery operators, 82 assemblers, 83 drivers and mobile plant operators, and 93 laborers in mining, construction, manufacturing, and transport.

expenditure of the enterprise group in the same region, it suggests that there are colocation advantages between manufacturing and R&D.

A third factor, which is also emphasized in Section 2, is that technology and knowledge transfer from R&D carried out at universities and colleges in a region could strengthen and improve the internal R&D capability of corporations located in the region. To capture the relationship between the extent of R&D carried out at universities and colleges in a region and the propensity of corporations to conduct R&D in the region, we created a variable RD_{rt-1}^{uni}, which measures the R&D expenditure at universities and colleges at the regional level. We relate this to the total R&D expenditure at universities and colleges in Sweden, SRD_{rt-1}^{uni}, which is then included in equation (1). Table 4 presents data on RD_{rt-1}^{uni} and SRD_{rt-1}^{uni} (in brackets) in 2001 and 2019.

Table 4 R&D expenditure in the academic sector, including total expenditures and expenditures in science and technology (S&T), in FA-regions, in 2001 and 2019; 2019 prices, million SEK.

FA-region	**R&D 2019**		**R&D 2001**	
	S&T	Total	S&T	Total
Stockholm-Uppsala	6,589	18,638	4,319	11,673
	(39.2)	(44.6)	(40.7)	(45.5)
Göteborg	3,198	6,529	2,071	4,265
	(19.0)	(15.6)	(19.5)	(16.6)
Malmö-Lund	2,653	6,448	1,716	3,983
	(15.6)	(15.4)	(16.2)	(15.5)
Linköping-Norrköping	1,056	2,147	584	1,258
	(6.3)	(5.1)	(5.5)	(4.9)
Luleå	812	950	491	563
	(4.8)	(2.3)	(4.6)	(2.2)
Umeå	733	3,423	474	2,010
	(4.4)	(8.2)	(4.5)	(7.8)
Other	1,776	3,637	946	1,922
	(10.6)	(8,7)	(8.9)	(7.5)
Total expenditure	16,817	41,772	10,601	25,674
S&T share	40.3		41.3	
Gini coefficient	0.90	0.91	0.91	0.92

Notes: Within the parentheses is the FA-regions' share of total R&D expenditure in all regions. S&T share is R&D expenditure in science and technology as a share of total R&D expenditure in all scientific fields.

Clearly, most of the R&D that is conducted in the academic sector is done in Stockholm-Uppsala (45 percent). Next come Göteborg and Malmö-Lund (19 and 16 percent, respectively), and then Umeå (8 percent) and Linköping-Norrköping (6 percent). Together, 89 percent of all R&D in the academic sector is carried out in these FA-regions. In other words, the bulk of academic research is concentrated in a few regions. In most other regions, it is quite modest. The pattern also seems to have been quite stable over time. The Gini coefficient is almost the same in 2019 as in 2001 – just over 0.9 – which is also the same value of the Gini coefficient for business R&D expenditure (see Table 2).[33]

In addition to total R&D expenses, we also report in Table 4 costs for R&D in science and technology (S&T). It is perhaps from this field of science above all that one would expect the knowledge transfers to be of particular importance for many of the manufacturing enterprise groups included in our analysis. Approximately 40 percent of the total R&D expenditures in the academic sector is spent in this area. However, the share of science and technology varies greatly between regions; in Luleå, the percentage is 85 percent, while in Umeå, it is only 21 percent; in Linköping-Norrköping and Göteborg, it is 49 percent, while it is 35 percent in Stockholm-Uppsala. In our estimations of equation (1), we use region *r*'s share of total R&D spending in academia and region *r*'s share of science and technology R&D spending as alternative measures of SRD_{rt-1}^{uni}.

Another factor that can attract investment in R&D in a region is the region's availability of qualified labor capable of performing R&D, potential R&D employees. When estimating the model in equation (1), we make use of three

[33] If we exclude the expenses for R&D from total academic expenses — a measure of the costs for education, premises, joint administration, etc., at the FA-region level — and then calculate the Gini coefficient, these expenditures are less regionally concentrated than R&D expenditures; the Gini coefficient for 2019 is 0.84. One explanation for this is that the small- and medium-sized universities and colleges, which tend to be located in medium-sized FA-regions, are more focused on basic higher education, while the large universities, which are we find to a greater extent in the large FA-regions, are more concentrated on research and postgraduate education. For these expenses, however, it still does not appear that there has been any change in the degree of concentration between 2001 and 2019; the Gini coefficient is almost the same in 2001 as in 2019 (0.83).

different measures of such a variable, $E_{rt-1}^{r\&d}$. The first is based on our observation that in enterprise groups with significant R&D expenditures and in industries with extensive R&D activities, there are two occupational groups in particular that are especially well represented: occupations with requirements for in-depth university competence in science and technology (SSYK 21) and in IT (SSYK 25). Accordingly, our first measure of potential R&D workers is the number of employees in such occupations (R&D occupations) at the regional level. Our second and third measures relate to the level of education of the individuals, the second being people who have postgraduate education, while the third is broader and includes everyone with a postsecondary education of three years or more in an FA-region. When we create these variables, we remove employees in the individual enterprise group *i* who meet the condition for potential R&D employees. The variable included in the estimated model is the share of potential R&D employees in region *r* of the total number in all regions, $SE_{rt-1}^{r\&d1}$.

The model in equation (1) also includes a variable that controls how enterprise group *i* develops over time, E_{it-1}, employment in enterprise group *i* lagged two years. A further variable is included that intends to pick up trends and cycles in region *r*, GRP_{rt-1} , the sum of the labor income of the employees in the business sector in region *r* at time *t-1*.

Finally, our model in equation (1) contains enterprise group-specific fixed effects, γ_i, which means that what we capture in the model are changes within an enterprise group, and year-specific fixed effects, γ_t. However, we do not include region-specific effects γ_r. This is because the majority of our regional variables are rather sluggish over time. To be able to capture their relationship to the dependent variable at all, we let our estimates reflect both the time and cross-sectional variation in these variables.

Based on data on R&D expenditure at the enterprise group level in the business sector from Statistics Sweden's survey, we create a dataset that spans the period 2001 to 2019 with observations every two years. We start in 2001 because this is the first year that there was a complete occupational register. In the survey, data on enterprise groups' expenditure on R&D are available at the county level, and in Section 3.2, we described how we obtain data on the dependent variable, R&D expenditure at the FA-region level, RD_{irt}. Since we work with lagged explanatory variables, R&D expenditures for 2003 are the first to be included in our econometric estimates.

Once the dependent variable RD_{irt} is created, it is relatively easy to generate the variables intended to capture external agglomeration, SRD_{nrt-1} and $SRD_{(n)rt-1}$, because we know in which industry *n* and region *r* an enterprise group *i* has R&D activities.

We also include, as noted above, observations in the dataset if enterprise group *i* has employees in FA-region *r* at time *t* but no R&D expenditures; then, we assume that $RD_{irt} = 0$. Since enterprise group *i* has employees in region *r*, the region could potentially receive R&D expenditure from the enterprise group in the future. The fact that it does not currently invest in R&D in the region is valuable information that should be taken into account when the model in equation (1) is estimated.

Characteristics of the unbalanced panel that we create for the period 2003 to 2019 are presented in Table 5.

Table 5 Characteristics of the panel

Year in panel	Number of enterprise groups	Cumulative share	Number of observations	Cumulative share	R&D expenditure	Cumulative share
9	43	5	6,442	29	331,193	62
8	22	7	1,504	35	12,689	65
7	21	9	1,643	43	22,522	69
6	43	14	1,812	51	43,987	77
5	53	20	1,574	58	30,154	83
4	79	29	2,780	70	19,132	87
3	112	41	1,526	77	20,252	90
2	243	68	2,792	89	42,159	98
1	296	100	2,464	100	8,407	100
Total	912		22,537		530,494	

Notes: Because we lag the explanatory variables, nine years are included in the panel. The R&D expenditures are in million SEK at 2019 prices. Cumulative shares are in percentages.

Table 5 shows that there are 912 unique enterprise groups in the panel and that the total number of observations is 22,537.[34] The total R&D expenditure of these enterprise groups over the study period is approximately 530 billion. The enterprise groups that have been in the panel for at least five years account for 83 percent of the R&D expenditures and 58 percent of all observations but make up only 20 percent of all enterprise groups.

A major concern with the specified model in equation (1) is that some of the explanatory variables are very highly correlated; that is, we have problems with multicollinearity. This is evident from the correlation matrix in Table 6.

Table 6 Correlation matrix with a selection of explanatory variables

	SRD_{nr}	$SRD_{(n)r}$	SE_r^{man}	SRD_r^{uni1}	$SE_r^{r\&d1}$	GRP_r	E_i
SRD_{nr}							
$SRD_{(n)r}$	0.59						
SE_r^{man}	0.25	0.27					
SRD_r^{uni1}	0.64	0.95	0.28				
$SE_r^{r\&d1}$	0.63	0.96	0.28	0.99			
GRP_r	0.60	0.91	0.27	0.93	0.94		
E_i	-0.11	-0.17	-0.23	-0.17	-0.16	-0.16	

Notes: In the correlation matrix, we report only one of the measures of the share of academic R&D expenditure in FA region *r*, SRD_r^{uni1}, namely, total R&D expenditure. The same applies to the measures of the share of potential R&D employees in region *r*, $SE_{rt-1}^{r\&d1}$, where we report the correlations for the share of employees in R&D occupations in FA-region *r*. The correlations differ only marginally if we use the alternative measures for these variables, i.e., the share of employees with postgraduate degrees, $SE_{rt-1}^{r\&d2}$, or long periods of university education in FA-region *r*, $SE_{rt-1}^{r\&d3}$.

As we can see in Table 6, there is a very strong correlation (shaded) between the R&D carried out outside the enterprise group's own industry, $SRD_{(n)r}$, the total academic R&D, SRD_r^{uni1}, the people employed in R&D occupations (potential R&D employees), $SE_r^{r\&d1}$, and the sum of labor income in the business sector, GRP_r, for a given region. Total R&D expenditures in academia, SRD_r^{uni1}, are also highly correlated with employment in R&D occupations, $SE_r^{r\&d1}$, and with total

[34] Totally, there are 992 unique enterprise groups that carry out business sector R&D. Internal agglomeration may only arise in enterprise groups with manufacturing activities. Therefore, we constrain our sample to enterprise groups that have employees in manufacturing occupations (m occupations). These means that 80 enterprise groups (just over 8 percent) are excluded.

regional labor income in the business sector, GRP_r, and this also applies to the correlation between the latter two variables. This means that it is difficult to include these variables simultaneously in the same specification. As a consequence, it becomes problematic to separate the individual impact of these factors on the location of business sector R&D in different regions.

4.2 Empirical results

Table 7 presents the main results from our estimations of the model in equation (1). These estimates should rather be considered as correlations than as causal effects. However, a number of the factors which in this econometric analysis turn out to be related to where the enterprise groups locate their R&D also appear as important motives when the enterprise groups themselves, in Section 4.3, are asked about the driving forces behind their location of their R&D activities. Overall, this could give room for a more causal interpretation, that is to say that these factors might have an effect on where the enterprise groups locate their R&D.

Table 7 Factors affecting R&D location at the regional level. Poisson pseudo maximum likelihood (PPML). Dependent variable: R&D expenditure in enterprise group *i* in FA region *r* at time *t*

	(1)	(2)	(3)	(4)	(5)	(6)
SRD_{nrt-1}	0.687	0.306				
	(0.82)	(0.24)				
$SRD_{(n)rt-1}$	2.890	3.649				
	(1.89)	(2.77)				
SE_{rt-1}^{man}		3.200	3.270	3.265	3.280	3.273
		(1.92)	(1.93)	(2.00)	(1.96)	(1.95)
SRD_{rt-1}^{uni1}			2.152			1.801
			(5.14)			(0.63)
SRD_{rt-1}^{uni2}				9.116		
				(10.80)		
$SE_{rt-1}^{r\&d1}$					4.996	0.864
					(6.59)	(0.14)
E_{it-1}	0.001	0.032	0.029	0.027	0.028	0.029
	(0.07)	(1.26)	(1.50)	(1.48)	(1.49)	(1.51)
GRP_{rt-1}	0.004	0.003	-0.001	-0.006	-0.000	-0.001
	(1.13)	(0.67)	(-0.99)	(-1.72)	(-0.19)	(-0.98)
Number of observations	22,537	22,537	22,537	22,537	22,537	22,537
Enterprise groups	912	912	912	912	912	912

Notes: Reported z-values within parentheses are based on robust standard deviations calculated according to Wooldridge (1999).

In Table 7, specification (1), we report results for whether the potential for external knowledge transfer (spillovers) in the same FA-region impacts whether an enterprise group is willing to conduct R&D in the region. In other words, we examine the relationship between opportunities for knowledge transfer (spillovers) between enterprise groups within the same industry, SRD_{nrt-1}, or between enterprise groups in different industries, $SRD_{(n)rt-1}$, and enterprise groups' investments in R&D at the regional level. Only the estimated coefficient for $SRD_{(n)rt-1}$ is positive and significant (not quite at the 5 percent level). Enterprise groups thus seem to be inclined to locate their R&D in regions where enterprise groups in other industries carry out relatively much of their R&D.

In the remaining specifications (2) to (6), we also examine whether colocation of R&D and manufacturing (*internal agglomeration*) plays a role in the location of R&D activities. The positive coefficient we obtain for SE_{irt-1}^{man}, with a significance around the 5 percent level, suggests that this is the case; the greater the share of manufacturing jobs that an enterprise group has in a region, the higher the enterprise group's regional R&D spending tends to be. Notably, in specification (2), when we add the variable SE_{rt-1}^{man}, the estimated coefficient of $SRD_{(n)rt-1}$ becomes larger than that in specification (1) and is also clearly significant.

In specifications (3) and (4), we then analyze how academic R&D expenditure at the regional level is related to the location of enterprise R&D investments. In specification (3), we focus on the regional share of total R&D expenditure in academia, SRD_{r}^{uni1}, while in specification (4), we limit ourselves to the regional share of total R&D expenditure in science and technology, SRD_{r}^{uni2}. From Table 4 above, we know that the correlation between $SRD_{(n)rt-1}$ and SRD_{r}^{uni1} is very high (0.95). We thus exclude the variable for potential knowledge transfers between industries $SRD_{(n)rt-1}$ in specifications (3) and (4). The very strong correlation between SRD_{r}^{uni1} and the regional supply of potential R&D employees, $SE_{rt-1}^{r\&d1}$ (0.99), indicates that we will also have problems if we include these variables in the same specification, thus we also refrain from this.

The estimated coefficient on SRD_{rt-1}^{uni1} in specification (3) is positive, as expected, and clearly significant. In specification (4), the estimated coefficient of SRD_{rt-1}^{uni2} is also positive but markedly larger and moreover has a significantly higher z-value. We interpret this to mean that the extent of academic R&D in science and technology in a region appears to be particularly important for whether enterprise groups locate their R&D there.

In specification (5), we study how enterprise groups' R&D investments covary with the regional availability of potential R&D employees, that is, the region's share of employees in R&D occupations, $SE_{rt-1}^{r\&d1}$. The estimate for $SE_{rt-1}^{r\&d1}$ in specification (5) is positive and clearly significant; the greater the relative availability of potential R&D employees in a region, the more R&D investments are made by enterprise groups there. If we estimate specification (5) using the alternative measures of the FA-regions' shares of potential R&D employees we obtain similar results.[35]

Finally, specification (6) illustrates what happens when very highly correlated variables, such as $SRD_{rt-1}^{uni1}$and $SE_{rt-1}^{r\&d1}$, are simultaneously included in the estimated model; none of the coefficients for these variables then turn out to be significant. This can be compared to the results in specifications (3) and (5), where these variables are included separately.

To summarize, our econometric results suggest that the presence of extensive potential for external knowledge transfer (spillovers) within the same region appears to matter for where enterprise groups locate their R&D activities. They also indicate that other important determinants of where enterprise groups locate their R&D are the extent of academic R&D carried out within a region – particularly in science and technology – as well as the regional availability of potential R&D employees. Finally, the results provide econometric evidence that colocation between manufacturing and R&D is an important factor for in which region enterprise groups locate their R&D in Sweden.

4.3 What do the enterprise groups themselves say is important?

We will now compare our econometric results with what enterprise groups themselves state as important motives when they decide where to locate their R&D activities.

In a survey carried out every two years, 20 Swedish multinational enterprises are asked about their R&D expenditure in different countries and their underlying motives for locating their R&D activities to a certain country. The motives that are examined are:

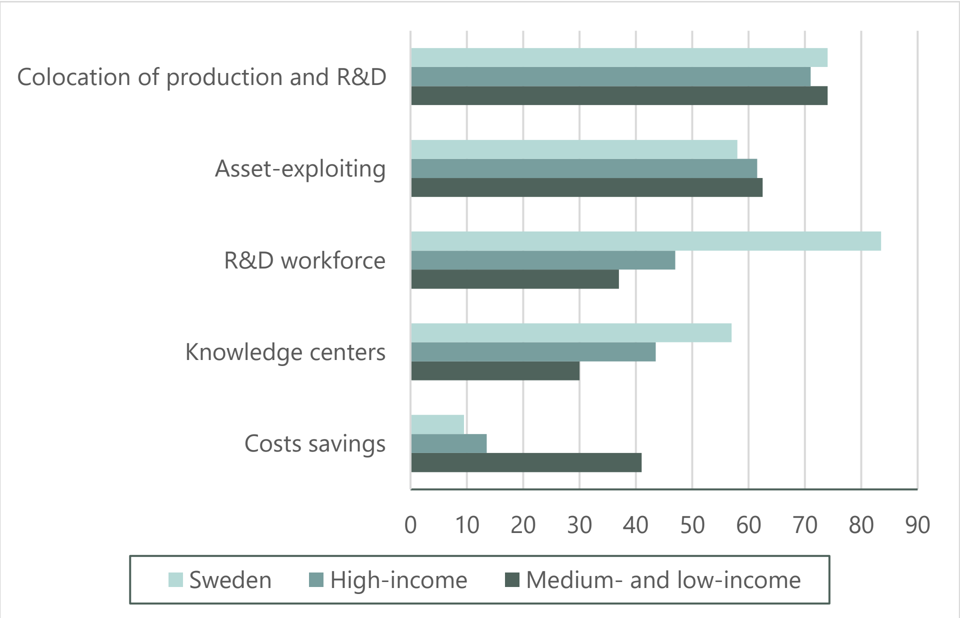
[35] Appendix Table A1 shows the result if share of share of employees in R&D occupations $SE_{rt-1}^{r\&d1}$ is replaced either by share of employees with postgraduate degrees $SE_{rt-1}^{r\&d2}$ or long periods of university education $SE_{rt-1}^{r\&d3}$. In both cases the estimated coefficients are somewhat smaller but clearly significant.

1) **Colocation of production and R&D**: Production units require R&D activities to be located to the same country or region.
2) **Asset-exploiting**: The companies need to adapt the product or process to specific customer or market needs.
3) **R&D workforce**: Access to qualified labor with R&D skills
4) **Knowledge centers**: There are important knowledge centers in the country or region, for example leading universities or business clusters
5) **Costs savings**: The location of the R&D-investment is expected to provide cost savings

The enterprise groups have graded the motives for each country of establishment where they stated that they conduct R&D activities. They indicate whether the motives match: very poorly, fairly poorly, neither well nor poorly, fairly well or very well.

In Figure 4, we present the results from the surveys carried out for the years 2019 and 2021.

Figure 4 Driving forces behind Swedish multinational enterprises' location of their R&D activities. Share who answered that the motive matches fairly well or very well. Percent.



Notes: Both for the years 2019 and 2021, the survey is answered by 21 Swedish multinational enterprise groups. The number of observations for Sweden as a location is 21 both 2019 and 2021, for high-income countries 146 in 2019 and 144 in 2021, and for low- and middle-income countries 104 in 2019 and 106 in 2021.

Source: Tillväxtanalys (Growth Analysis), Forskning och utveckling i internationella företag (Research and development in international enterprises) 2021 och 2019.

Figure 4 shows that colocation of R&D and production is an essential motive when Swedish multinational enterprises are to locate their R&D. Just over 70 percent state this as an important reason for where to carry out their R&D activities in Sweden. More or less the same result applies to the location of R&D in other countries. Another factor of great importance, also valid for all types of countries, for how extensive the R&D activities are in a country is requirements to adjust products and processes to specific customer preferences and market needs (*asset-exploiting*).

Interestingly, we can see from Figure 4 that the responding Swedish multinational enterprises consider abundance of qualified R&D personnel and proximity to important knowledge centers as particularly important factors when locating R&D in Sweden. On the other hand, cost-saving reasons are instead of less importance when locating R&D in Sweden.

Overall, we conclude that the results from our econometric analysis agree quite well with what the enterprises state in the survey as important motivations for where to locate their R&D.

5. Concluding comments

Almost all reported R&D expenditures in the Swedish business sector – 93 percent – are carried out within multinational enterprises (Swedish-owned or foreign-owned). Furthermore, R&D expenditures are concentrated in a few enterprise groups and FA-regions in Sweden. Stockholm-Uppsala and Göteborg account for 64 percent, and together with Malmö-Lund and Linköping-Norrköping for over 80 percent.

Agglomeration effects seem to play an important role in the location of business sector R&D. The lion’s share of the new knowledge that emerges in the business sector is generated in the four largest FA-regions above, while at the same time, there seems to be a significant spread of knowledge between business groups in different industries within the same FA-region. This result is probably largely because employees can move relatively friction-free between enterprise groups within the same FA-region and because large and densely populated regions offer ample opportunities for face-to-face meetings.

In the large FA-regions above, a significant part of the R&D is carried out in academia. They account for approximately 80 percent of all academic R&D in Sweden. This means that the transfer of knowledge from academic R&D to the surrounding business sector is likely to be considerable in these regions and is an incentive for enterprise groups to invest in R&D there.

We observe that the availability of potential R&D employees is particularly high in the large FA-regions; the share of employees with long postsecondary education is the highest in the country. A large part of those who spend a longer time in postsecondary education, especially those who receive a postgraduate degree, do so in these large regions. Moreover, the metropolitan regions receive large net inflows of young highly educated people, while small- and medium-sized regions show significant migration losses.[36] However, there does not seem to have been an increased concentration of business R&D expenditure in the larger FA-regions recently.

An interesting result from the econometric analysis is that we find evidence for the occurrence of internal agglomeration. Enterprise groups that carry out manufacturing activities tend to conduct significant parts of their R&D in the same region as their manufacturing operations. We note that in a number of medium-sized FA regions, such as Gävle and Ludvika, there are enterprise groups with extensive activities in R&D that also have considerable parts of their manufacturing activities there. The colocation of R&D and production contributes

[36] Moreover, Eliasson et al. (2020) shows that the proportion of young highly educated people who move to larger regions increases significantly in the upper part of the grade distribution from upper secondary school. The higher the upper secondary school grades attained, the greater the proportion of young highly educated people who move from smaller to larger regions. Moves up the regional hierarchy are also found to be positively associated with a favorable family background as measured in terms of parental education level and income.

positively to joint problem solving, and tacit knowledge can be transferred between R&D employees and those working in production and vice versa.

The fact that many enterprise groups with their primary location in medium-sized FA-regions have both extensive production and R&D activities in these regions is a sign that there are substantial colocation advantages between manufacturing and R&D activities. To be able to maintain qualified R&D activities and thus to remain internationally competitive, it is essential to attract and retain competent employees. This is a major challenge for enterprise groups in medium-sized FA-regions, where it appears to be markedly more difficult to attract qualified labor. On the other hand, the recruitment of manufacturing staff can probably take place locally.

As we have found in the paper, the new knowledge generated in the business sector in the large FA-regions is significant, and moreover, the spread of knowledge between enterprise groups and between academia and enterprise groups appears to be extensive in these regions. These are factors of great importance for economic growth not only in these regions but also for the whole country. Therefore, large FA-regions must be given proper conditions to continue to develop and grow, for example, by ensuring necessary investments in housing and infrastructure in these regions.

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Appendix

Table A1 Factors affecting R&D location at the regional level. Poisson pseudo maximum likelihood (PPML). Alternative specifications. Dependent variable: R&D expenditure in enterprise group *i* in FA region *r* at time *t*.

	(1)	(2)
SRD^{man}_{rt-1}	3.252	3.261
	(1.89)	(1.91)
$SE^{r\&d2}_{rt-1}$	4.075	
	(3.46)	
$SE^{r\&d3}_{rt-1}$		4.487
		(3.35)
E_{it-1}	0.030	0.030
	(1.50)	(1.48)
GRP_{jt-1}	0.000	0.000
	(0.29)	(0.48)
Number of observations	22,537	22,537
Enterprise groups	912	912

Notes: See Table 7. $SE^{r\&d2}_{rt-1}$ is the share of postgraduate employees in region *r* of the total number of postgraduate employees in the business sector, and $SE^{r\&d3}_{rt-1}$ is the corresponding share with significant amounts of postsecondary education—3 years or longer in region *r*.