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Location of R&D within Swedish Multinational Enterprises

Swedish MNEs account for 46 percent of the R&D expenditures in the Swedish business sector and 50 percent of their R&D is conducted overseas. Recently, this share has been decreasing. What determines the localization of R&D in Sweden and abroad? Is R&D within Swedish MNEs moving away from Sweden and has Sweden become less attractive as an investment country for R&D?

Tillväxtanalys
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Förord

Tillväxtanalys uppdrag är att utvärdera och analysera effekterna av statens insatser för en hållbar nationell och regional tillväxt. Vi ska också ge underlag och rekommendationer för utveckling, omprövning och effektivisering av politiken.

Syftet med den här rapporten är att analysera vilka faktorer som påverkar lokaliseringen av forskning och utveckling (FoU) inom svenska multinationella företag (MNF) i olika länder (inklusive Sverige). Den syftar också till att undersöka hur Sverige är positionerat när det gäller dessa faktorer i ett internationellt perspektiv. Rapporten är skriven av Kent Eliasson, Pär Hansson och Markus Lindvert.

Pär Hansson har varit projektledare. I projektet har också Kent Eliasson och Markus Lindvert medverkat. Projektets kontaktperson på Näringsdepartementet har varit Altin Veisju. Vi har även fått synpunkter från Peter Frykblom, Marie Gartell och Håkan Nordström.

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Marie Gartell, avdelningschef, Tillväxtanalys

Contents

Sammanfattning

Svenska multinationella företag (MNF) står för en betydande del av utgifterna för forskning och utveckling (FoU) i näringslivet i Sverige (46 procent) och det har länge funnits ett stort intresse för vad som bestämmer lokaliseringen av FoU. Det beror på att FoU förväntas ha positiva effekter på tillväxten, skapa kvalificerade jobb samt öka tillgången på ny kunskap i ett land. Syftet med denna studie är att analysera vilka faktorer som påverkar lokaliseringen av FoU inom MNF i olika länder (inklusive Sverige).

Det visar sig att det mellan 1999 och 2019 har skett en klar minskning av den andel FoU som utförs inom svenska MNF i Sverige. Är detta en indikation på att Sverige blivit mindre attraktivt som investeringsland för FoU? En slutsats i rapporten är, att när hänsyn tas till olika faktorer som förväntas påverka var lokaliseringen av FoU sker, tycks detta inte vara fallet.

Internationaliseringen av FoU inom svenska MNF har tilltagit på senare tid – inte minst i Kina har FoU utgifterna ökat kraftigt

Både i moderföretagen i Sverige och i dotterföretagen utomlands har FoU-utgifterna inom svenska MNF ökat. Det senare gäller såväl för dotterföretagen i höginkomstländer som i medelinkomstländer. Däremot har den andel FoU som utförs i dotterföretagen stigit från 42 procent till 50 procent mellan 1999 och 2019. Detta beror framför allt på att en allt större andel FoU har förlagts till dotterföretagen i medelinkomstländer, inte minst till Kina. Kina är idag det land, näst efter USA, i vilket dotterföretagen till svenska MNF bedriver mest FoU.

Internationaliseringen är emellertid inte lika omfattande som i andra delar av värdekedjan

Sysselsättningen inom svenska MNF har vuxit snabbare i dotterföretagen utomlands än utgifterna för FoU. Andelen sysselsatta i dotterföretagen utomlands har stigit från 71 procent till 83 procent.[1] Att enbart 17 procent av sysselsättningen finns i Sverige, medan 50 procent av FoU verksamheten fortfarande sker i Sverige tyder på att produktion och försäljning är avsevärt mer internationaliserade än FoU.

Snabb tillväxt, hög teknologisk nivå, god tillgång på kvalificerad arbetskraft och ett starkt skydd för immateriella rättigheter attraherar investeringar i FoU

Stora länder med snabb ekonomisk tillväxt har dragit till sig investeringar i FoU från svenska MNF. Det gäller också länder där utgifterna för FoU som andel av BNP är höga och där en stor andel av den ekonomiskt aktiva befolkningen har en eftergymnasial utbildning. Bidragande till att svenska MNF har ökat sina investeringar i FoU utomlands, särskilt i en del medelinkomstländer med hög tillväxt, är ökad egen närvaro med

[1] Lägg märke till att detta gäller för de 20 svenska MNF som har de största FoU-utgifterna i Sverige och inte för alla svenska MNF för då är andelen sysselsatta utomlands klart lägre.

produktion och försäljning i dessa länder. I dessa länder har man också på senare år förbättrat sitt skydd för immateriella rättigheter. Detta är dock ännu inte är på samma nivå som i flertalet höginkomstländer.

Höga löner för välutbildad arbetskraft och höga bolagsskatter är inte uppenbart negativa vid lokaliseringen av FoU

Att höga löner för kvalificerad arbetskraft (ingenjörer) i investeringsländerna inte förefaller hämma lokaliseringen av FoU kan bero på att hög lön också avspeglar arbetskraftens kvalitet. Noteras bör också att det råder stark samvariation mellan länder när det gäller utgifter för FoU som andel av BNP, andel kvalificerad arbetskraft och lönen för ingenjörer. Det gör att det kan vara svårt att dra säkra slutsatser om sambanden.

Det finns empiriska belägg för att höga skatter i värdländer verkar återhållande på direktinvesteringar i allmänhet. När det gäller svenska MNF:s investeringar i FoU i andra länder finner denna studie däremot inget samband mellan nivån på bolagsskatten och omfattningen av FoU investeringarna i ett land.

Ett annat intressant resultat är att det geografiska avståndet mellan Sverige och värdländerna inte tycks ha samma negativa inverkan på investeringar i FoU som på direktinvesteringar generellt. En förklaring till detta kan vara att kunskapsflöden sker mer friktionsfritt mellan olika delar av MNF i olika länder än transaktioner med insatsvaror mellan länder.

Den teknologiska nivån och innovationsaktiviteten är hög i Sverige samtidigt som skyddet för immateriella tillgångar är relativt starkt

Jämfört med andra investeringsländer är FoU-utgifterna i relation till BNP hög i Sverige. Detsamma gäller för antalet forskare per 1000 anställda. Ett index som jämför styrkan på patentskyddet i olika länder visar att detta, liksom i andra höginkomstländer, är starkt. Varken löner för kvalificerad arbetskraft (jämfört med andra höginkomstländer) eller bolagsskatterna är särskilt höga i Sverige.

Tidigare erfarenheter och omfattning av direktinvesteringar i ett land liksom likheter avseende institutioner mellan länder bidrar till ökade investeringar i FoU

En mycket viktig bestämningsfaktor för huruvida svenska MNF investerar i FoU i ett land är om landet redan sedan tidigare är ett betydande lokaliseringsland för koncernen för annan verksamhet än FoU, som produktion eller försäljning. Likheter avseende institutioner, som att ett land under en längre tid varit medlem i EU, är en annan faktor som bidrar till att öka investeringarna i FoU.

Lokaliseringen av FoU i svenska MNF är hemmarknadskoncentrerad, ”home-market biased”, och denna koncentration har förstärkts över tid

Om hänsyn tas till olika faktorer som antas påverka lokaliseringen av FoU till ett land visar det sig att investeringarna i FoU i svenska MNF i Sverige – allt annat lika – är högre i Sverige. Med andra ord är den hemmamarknadskoncentrerad (”home-market biased”). Dessutom förefaller denna hemmarknadskoncentration till och med har förstärkts under den studerade perioden. Det framgår nämligen att den ökade andelen sysselsatta i dotterföretagen utomlands och en snabbare tillväxt i många andra viktiga investeringsländer än i Sverige inte har lett till så omfattande FoU investeringar utomlands som kunnat förväntas. En tolkning av detta är att Sverige som investeringsland för FoU inte har försämrats över tid utan snarare det motsatta.

Rapportens genomförande

I rapporten skattas en modell på data över FoU-utgifter i svenska MNF på koncernnivå i olika länder mellan 1999 och 2019 som förklaras med karakteristika på koncern- och ländernivå. Data kommer från en undersökning som Tillväxtanalys tillsammans med SCB genomför vartannat år, där 20 svenska MNF (som har de största FoU-utgifterna i Sverige) tillfrågas om deras FoU-utgifter i moderföretaget Sverige och i dotterföretagen i olika länder utomlands.

Summary

Swedish multinational enterprises (MNEs) account for a significant part of the expenditure on research and development (R&D) in the business sector in Sweden (46 percent), and there has long been great interest in what determines the location of R&D. This is because R&D is expected to have positive effects on growth, create qualified jobs and increase the amount of new knowledge in a country. The purpose of this study is to analyze the factors that affect the location of R&D within MNEs in different countries (including Sweden).

It turns out that between 1999 and 2019, there was a clear reduction in the proportion of R&D carried out within Swedish MNEs in Sweden. Is this an indication that Sweden has become less attractive as an investment country for R&D? One conclusion in the report is that when different factors are considered that are expected to affect where the location of R&D takes place, this does not seem to be the case.

Recently, the internationalization of R&D within Swedish MNEs has increased, especially in China, and R&D expenditures have grown sharply

Both in the parent companies in Sweden and in the subsidiaries abroad, R&D expenditure within the Swedish MNEs has increased. The latter applies to affiliates in high-income countries as well as in middle-income countries. On the other hand, the share of R&D carried out in the subsidiaries abroad rose from 42 percent to 50 percent between 1999 and 2019. This is mainly because an increasing share of R&D has been localized to affiliates in middle-income countries, especially in China. China is today the country, second only to the United States, in which the subsidiaries of Swedish MNEs conduct the most R&D.

However, internationalization is not as large-scaled as in other parts of the value chain

Employment in Swedish MNEs has grown faster in subsidiaries abroad than expenditures on R&D. The proportion employed in affiliates abroad has risen from 71 percent to 83 percent.[2] The fact that only 17 percent of the employment is in Sweden, while 50 percent of R&D activities still take place in Sweden, indicates that production and sales are considerably more internationalized than R&D.

Rapid growth, high technology level, abundant supply of skilled labor, and strong protection of intellectual property rights attract investment in R&D

Large countries with rapid economic growth have attracted investments in R&D from Swedish MNEs. This also applies to countries with high R&D expenditures to GDP and large proportions of the economically active population have post-secondary education. Another contributing factor to the fact that Swedish MNEs have increased investments in

[2] Note that this applies to the 20 Swedish MNEs that have the largest R&D expenditures in Sweden and not to all Swedish MNEs because then the proportion employed abroad is much lower.

R&D abroad, especially in some middle-income countries with high growth, is their growing presence in production and sales in these countries. In recent years, these countries have also improved their protection of intellectual property rights. However, this is not yet at the same level as in most high-income countries.

High wages for skilled labor and high corporate taxes are not clearly negative determinants of the localization of R&D

The fact that high wages for skilled labor (engineers) in the investment countries do not seem to hamper the location of R&D may be because those high wages also reflect the quality of the labor force. It should also be noted that there are strong correlations among countries in terms of R&D expenditure as a share of GDP, the share of skilled labor, and the salaries of engineers. This means that it can be difficult to draw definite conclusions about the relationships.

There is empirical evidence that high corporate taxes in host countries have a restraining effect on foreign direct investment in general. Regarding Swedish MNEs' investments in R&D overseas, however, this study finds no significant relationship between the level of corporate taxes and R&D investments.

Another interesting result is that the geographical distance between Sweden and the host countries does not seem to have the same negative impact on investments in R&D as on foreign direct investments in general. One explanation for this may be that knowledge flows take place more frictionlessly between different parts of the MNEs in different countries than transactions of input goods between countries.

The technological level and innovation activities are high in Sweden, while the protection of intangible assets is relatively strong

Compared with other investment countries, the ratio of R&D expenditure to GDP is high in Sweden. The same applies to the number of researchers per 1,000 employed. An index that compares the strength of patent protection in different countries shows that this, as in other high-income countries, is strong. Neither wages for skilled labor (compared to other high-income countries) nor corporate taxes are particularly high in Sweden.

Previous experiences from foreign direct investment in a country and similarities regarding institutions among countries contribute to increased investment in R&D

A very important determining factor for whether a Swedish MNE invests in R&D in a country is whether the country is already a significant location country for the MNE for activities other than R&D, such as production or sales. Similarities in institutions, including which countries have been members of the EU for a long time, are another factor that contributes to increased investment in R&D.

The location of R&D in Swedish MNEs is home-market biased and this concentration in Sweden has strengthened over time

It turns out that when controlling for factors that are assumed to affect the location of R&D in a country, the investments in R&D of Swedish MNEs in Sweden are higher than expected. In other words, they are home-market biased. Moreover, this concentration of R&D investment in Sweden even seems to have been strengthened during the period studied, because the increased share of employees in the subsidiaries abroad and faster growth in many other important investment countries than in Sweden has not led to as extensive R&D investments abroad as could be expected. One interpretation of this is that Sweden as an investment country for R&D has not deteriorated over time; rather, the opposite has occurred.

The empirical analysis in the report

The model estimated in the report is based on data on R&D expenditures in Swedish MNEs in different countries (including Sweden) between 1999 and 2019 that are explained with characteristics at the enterprise and country levels. Data come from a survey that the Swedish Agency for Growth Policy Analysis, together with Statistics Sweden, conducts every two years, where 20 Swedish MNEs (which have the largest R&D expenditures in Sweden) are asked about their R&D expenditures in the parents in Sweden and their affiliates in various countries abroad.

1. Introduction

A significant proportion of the research and development (R&D) carried out in the business sector is performed by multinational enterprises (MNEs).[3] Declining costs for transportation, information and communication, together with lower barriers to international trade and investment, have led to the increased fragmentation of functions within MNEs. This also applies to R&D, which has long been one of the least mobile activities within MNEs. However, over recent decades, we have observed an increasing internationalization of R&D[4] activities by MNEs, starting with expansions to developed countries, but lately also to emerging economies.

The traditional motive for MNEs to perform R&D in affiliates overseas is to adapt products and services to local market conditions and support their local manufacturing and sales operations (*asset exploiting*). The reason for localizing R&D abroad is thus essentially demand-oriented, and such activities are established in countries where an MNE already has significant manufacturing or sales operations.

A supply-oriented motive, and recently an increasingly more important reason for MNEs to carry out R&D in affiliates abroad is to tap into worldwide centers of knowledge particularly outstanding in fields that they want to develop (*asset augmenting*). Intensified global competition has forced companies to produce new commercially viable products more quickly, while knowledge has become increasingly scattered. To quickly understand and benefit from new technology, MNEs perform their own R&D in affiliates abroad located in places where significant R&D activities in fields of interest are conducted (*knowledge sourcing*).

The aim of the paper is to examine factors that affect the locations and scope of R&D activities within MNEs across countries. For that purpose, we use panel data on the R&D expenditure of Swedish MNEs in the parents at home and in their affiliates in different countries abroad from 1999 to 2019.

Sweden is an interesting country to study because it is one of the most R&D-intensive countries in the world.[5] Furthermore, Swedish MNEs account for 46 percent of the R&D expenditures in the Swedish business sector, and the enterprises in the panel are the Swedish MNEs with the largest expenditures on R&D in Sweden. In addition, we will show that during the studied period Swedish MNEs substantially increased their expenditure on R&D (and employment) overseas, especially in middle- and low-income countries.

Numerous empirical studies on the determinants of the location choice of foreign direct investment in general have been published.[6] However, one could argue that the

[3] In 2019, MNEs (Swedish MNEs and foreign-owned firms) accounted for 87 percent of the expenditure on R&D in Sweden, while their share of employment was much smaller, 41 percent.

[4] Internationalization of R&D means that firms conduct R&D in other countries than their home country (Dachs 2017).

[5] In 2019, the R&D expenditures as a share of GDP in Sweden amounted to 3.3 percent. Only Israel at 4.9 percent, Korea at 4.5 percent, Switzerland at 3.4 percent, and Taiwan at 3.4 percent had higher R&D intensities (UNESCO Institute for Statistics).

[6] Nielsen et al. (2017) reviewed and evaluated 153 quantitative studies on FDI location choice from 1976 to 2015.

determinants differ, or at least that the importance of a determinant varies among different activities along the value chain, for instance, between R&D and production. Moreover, policy-makers have a particular interest in the location of R&D, since R&D is expected to promote growth, create skilled jobs, and increase the availability of new knowledge in a country.

Despite the growing internationalization of R&D expenditure within MNEs, a large proportion of the R&D expenditures in Swedish MNEs still tend to be concentrated in the parents in Sweden. Is this due to a home-country bias in R&D? However, the share of R&D expenditures in Swedish MNEs conducted in Sweden has fallen over the studied period. Is this an indication of a less prevalent home-country bias in R&D or does it suggest that Sweden has become less attractive as an investment country for R&D?

A contribution of the paper is that we can use panel data at the enterprise level on both R&D expenditure and employment over a long period. This means, among other things, that we can exploit information from the panel about MNEs that, to begin with, not only have employment in a country but eventually also have R&D. Since R&D expenditure in an MNE in a country is our dependent variable in the econometric analysis, we will then have a substantial number of zero observations (positive employment, but no R&D). Therefore, to handle these zero observations, we follow a practice originating from the gravity equation literature[7] and estimate our econometric model with the Poisson pseudo maximum likelihood PPML method.

Athukorala and Kohpaiboon (2010), Siedschlag et al. (2013), and Castellani and Lavaratori (2018) are recent related studies of patterns and determinants of MNEs' location of R&D overseas using panel data.[8]

Athukorala and Kohpaiboon (2010) employ a similar approach to ours and examine R&D intensities in affiliates abroad by US-based manufacturing MNEs from 1990 to 2004. Their focus is on the relative importance of some policy-related variables in explaining variations across countries in R&D intensities. However, unlike our study, they are constrained to a panel with variations solely across countries and are therefore not able to consider heterogeneities among MNEs (or industries). They find that the key determinants of the R&D intensities of operations of US MNE affiliates abroad are market size, overall R&D capability, and cost of hiring R&D personnel. However, R&D-related tax incentives do not appear to be important in explaining intercountry differences in R&D intensities.

Siedschlag et al. (2013) and Castellani and Lavaratori (2018) pursue another approach. They estimate discrete choice models to analyze the locational decisions of R&D activities by multinational firms in regions of the European Union over the period 1999 to 2006 (Siedschlag et al. 2013) or in global cities from 2003 to 2014 (Castellani and Lavaratori 2018).

[7] See Santos Silva and Tenreyro (2006 and 2022)

[8] Since Swedish MNEs are such large investors in R&D, there are several studies on the internationalization of R&D in Swedish MNEs, e.g., Håkanson and Nobel (1993), Fors (1998), Granstrand (1999), and Ivarsson, Alvstam and Vahlne (2017).

The results of Siedschlag et al (2013) suggest that on average the location probability of a representative R&D foreign affiliates increases with agglomeration economies from foreign R&D activities, a region's knowledge base measured by human capital, proximity to centers of research excellence, and innovation capacity.

Castellani and Lavoratori (2018) focus on external location factors, which means that firms tend to break up their activities along the value chain and geographically spread out these activities in different locations, as well as on internal factors that lead firms to locate their value chain activities in the same location (colocation within the firm). They find that both external and internal factors matter. Firms want to locate R&D abroad in global cities where other firms have previously invested in R&D or production; they observe colocation between firms in the same location (external agglomeration economies). Additionally, they find that firms are inclined to locate R&D in global cities in which they themselves previously have located their R&D or production (intrafirm linkages).

To preview our results, we find that large, fast-growing countries and the importance of a country as a market for an MNE attract investment in the R&D of Swedish MNEs. Other factors that entice R&D investment are a high technological level, sufficient supply of qualified and well-educated workers, and satisfactory protection of intellectual property rights in the investment country. However, wages of skilled labor, corporate taxes, and distance to the investment country do not appear to be important for the localization of R&D. R&D investments within Swedish MNEs are home-market biased, i.e., given the conditions in the investment countries, we would have expected to observe a smaller share of R&D expenditure in Sweden. In fact, the home-market bias even seems to have been strengthened over the studied period.

The paper is structured as follows. In Section 2, we discuss, based on the previous literature, determinants of the location of R&D. In Section 3, we present our data and give some descriptions. Section 3.1 introduces the enterprise data of Swedish MNEs on R&D expenditure and employment and provides information on panel characteristics. Section 3.2 shows the development over the studied period in the Swedish MNEs of R&D expenditure and employment in the parents at home and in the affiliates abroad, in high-income and in middle- and low-income countries. Section 4 contains the econometric analysis. In Section 4.1, we specify the econometric model and show statistics on the explanatory variables, and we benchmark Sweden relative to other investment countries. In Section 4.2, we justify our use of PPML as an estimation method and present and discuss the results from the estimations. Section 5 summarizes and concludes the paper.

2. What determines the locations of R&D across countries?

According to the literature on the internationalization of R&D, knowledge sourcing is and has become an increasingly important motive for carrying out R&D in affiliates overseas.[9] High R&D intensities – R&D expenditures as a share of GDP – are an indicator of extensive knowledge production (innovation activity) and a high level of technological development in a country.[10] Consequently, we expect that Swedish MNEs are attracted to establish and conduct their R&D activities in research-intensive countries, especially in countries in which the research intensity in the industry of an MNE is considerable, i.e., the innovation activity in the location country is high in the industry in which an MNE operates.

Related to this is the access to researchers, or more generally to skilled labor, in the host country, particularly in the field in which the MNE operates. In general, however, an abundant supply of highly skilled labor (or particularly researchers) in the host country will facilitate the localization of a skill-intensive activity such as R&D abroad.[11]

Adapting products and technology to local conditions and providing technical backup for local manufacturing are other motives for overseas R&D activities. A large presence in terms of production and sales of an MNE and long previous experience in a market are thus supposed to be drivers for the MNE to establish demand-oriented R&D operations abroad. Unlike previous studies of determinants of R&D location within MNEs, we have access to panel data both on R&D expenditure and employment at the enterprise level in host countries and in the home country (Sweden), which means that we can construct measures of the importance of a host country and Sweden for an MNE, as well as how long it has been established in a host country (experience from the market).

Lower linguistic barriers and similar institutions may positively affect the tendency to locate R&D overseas. Therefore, we expect that Swedish MNEs would, all other things equal, be more likely to locate their R&D in English-speaking countries and in countries that have been long-term members of the EU (at least since 1995).

Reasonably, one can assume that the gravity model, which has proven to be a workhorse in explaining a broad range of international interactions, could be employed to determine R&D expenditures within MNEs across countries.[12] This means that a large market potential (size of the host countries' GDP) and fast-growing markets (GDP growth in host countries) are expected to entice FDI, production and sales, as well as R&D.

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[9] See, e.g., Almeida (1996), Florida (1997), Le Bas and Sierra (2002), von Zedtwitz and Gassmann (2002), Ambos (2005), OECD (2011) and Dachs (2017).

[10] Similar proxies have been commonly used in previous studies, see, e.g., Kumar (2001), Shimizutani and Todo (2008) and Siedschlag et al. (2013).

[11] A key finding in Thursby and Thursby (2006) is that the most important attractor (pull factor) for location of R&D is access to highly qualified R&D personnel. On the flip side of that (push factors) are skill shortage and a growing demand for engineers and scientists in the home country.

[12] Head and Mayer (2014) contains a comprehensive discussion about estimations and interpretations of the gravity equation for bilateral trade flows.

The conventional wisdom about the other fundamental gravity variable, geographic distance, is that it is negatively associated with a location of FDI abroad. Transportation and coordination costs are larger the more geographically dispersed the headquarters and foreign affiliates are within MNEs. However, for R&D, geographical distance might be a lesser obstacle because, in comparison with intermediate goods flows, knowledge transfer within MNEs occurs more frictionlessly between different parts of the MNE in various countries. Moreover, for leading MNEs to access the latest knowledge, it is sometimes an absolute necessity to set up R&D labs in highly specialized knowledge clusters even in distant locations (Castellani et al. 2013).

Factors that impede the propensity to establish and invest in R&D in another country (repelling factors) are such that they increase the costs of performing R&D in countries overseas, such as high wages of skilled labor and high corporate taxes.

Arguably, when an MNE chooses whether to locate in a host country (extensive margin), it is the total after-tax profit that counts, and thus, the relevant tax is the effective average tax rate (EATR). On the other hand, if an MNE considers whether it will expand an activity or not in a host country (intensive margin), the appropriate tax rate to employ is the effective marginal tax rate (EMTR).

Another factor that discourages investments is poor protection of intellectual property rights (IPR). A weak IPR regime increases the probability of imitation, which will erode an MNE's competitive edge, and this is particularly significant for new knowledge.[13] Therefore, a weak IPR regime in a country makes it less attractive for overseas R&D activities.[14]

Variation in R&D intensities among MNEs might depend on what the MNE produces or what service it provides and the production processes. More research-intensive MNEs – those with higher R&D expenditure as a share of employment − are supposed to be more inclined to offshore R&D overseas. Such MNEs have a greater need to tap into worldwide centers of knowledge and thus strive to a larger extent than less research-intensive MNEs to be present in clusters abroad where new knowledge is developed. Moreover, the development of research intensities among MNEs over time might differ.

Centrifugal factors, such as relatively high R&D intensities and good access to an abundant supply of skilled labor abroad, tend to pull away R&D from the home country (center) to affiliates overseas (into peripheral locations). Moreover, extensive expansion of operations in the subsidiaries abroad entails a need to also establish supporting R&D activities overseas.

However, there are also centripetal factors trying to keep R&D in the home country. One is a realization of economies of scale and scope. Indivisibles of R&D activities lead to economies of scale and knowledge spillovers between R&D activities in different technology fields and economies of scope. Another is that geographical decentralization of R&D could give rise to knowledge leakage to foreign competitors, which in turn could undermine an MNE's competitiveness. Centripetal factors could lead to home-market

[13] A survey by Mansfield (1994) on the importance of IPR regimes for investment showed that the respondents were most concerned about such regimes when R&D facilities were involved.

[14] Javorcik (2004) finds that weak protection deters foreign investors in technology-intensive sectors.

bias in R&D, i.e., that a major portion of R&D is still located in the home country (Belderbos et al. 2013).

3. Data and descriptions

3.1 Data on Swedish MNEs and panel characteristics

Our empirical analyses are mainly based on two unique data sources and are from the Swedish Agency for Growth Policy Studies (Growth Analysis). The first is data on R&D expenditure in Sweden and overseas in the 20 Swedish MNEs with the largest R&D expenditure in Sweden. The data come from a survey conducted by Statistics Sweden every two years.[15] Such data are available from 1997 to 2019. The second is data on employment in Swedish MNEs, in their Swedish parents and in their affiliates abroad, and are from the MNEs' annual accounts.[16] This means that we have access to panel data on R&D expenditure and employment in Swedish MNEs in the parent and in affiliates in different countries abroad.

From the data on R&D expenditure in Swedish MNEs, we create an unbalanced panel with observations every two years from 1997 to 2019. The panel is unbalanced because some MNEs exit the panel when they become foreign-owned or undergo large organizational changes, e.g., merging or divesting. The latter might mean that they obtained other ID numbers. If an MNE drops out from the panel, it is replaced by another Swedish MNE that enters the panel. This implies that there will always be approximately 20 Swedish MNEs in each survey. To this panel, we add data on the employment of the included Swedish MNEs in Sweden and in various countries overseas. Table 3.1 provides information about the characteristics of the created panel, for instance, how many MNEs are in the panel during the whole period (the balanced part) and the importance of these MNEs.

Table 3.1 Panel characteristics

Years in the panel	Number of MNEs	Cumulative share	Number of observations	Cumulative share	R&D FTE	Cumulative share
12	9	23.1	1,587	61,2	468,430	83.8
11	1	25.6	55	63.3	2,238	84.2
10	1	28.2	84	66.6	6,146	85.3
9	2	33.3	263	76.7	21,849	89.2
8	2	38.5	179	83.6	5,937	90.3
7	2	43.6	98	87.4	3,574	90.9
6	4	53.8	131	92.4	20,885	94.6
5	0	53.8	0	92.4	0	94.6
4	3	61.5	46	94.2	17,485	97.8
3	1	64.1	12	94.7	243	97.8
2	8	84.6	101	98.6	3,330	98.4
1	6	100.0	37	100.0	8,908	100.0
Total	39		2,593		559,026	

Note: R&D FTE is the number of yearly full-time equivalents in R&D.

First, we observe in Table 3.1 that there are 39 unique MNEs in the panel and that nine of these MNEs are permanent. Second, we can see that 60 percent of the observations are from the nine permanent MNEs, and in regard to the amount of R&D carried out, these

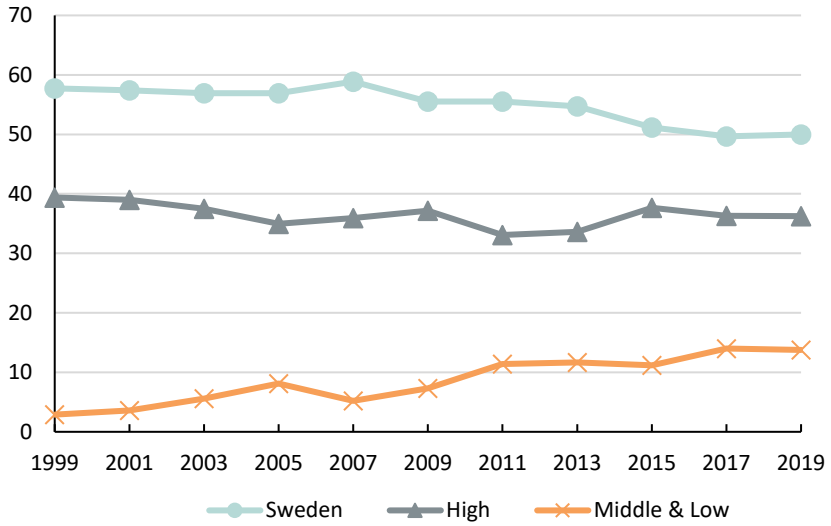
[15] Swedish Agency for Growth Policy Analysis, R&D in International Groups.
[16] Swedish Agency for Growth Policy Analysis, Swedish Enterprise Groups with Affiliates Abroad

MNEs account for more than 83 percent of the number of yearly full-time equivalents in R&D. In other words, the panel is heavily dominated by the permanent MNEs. Third, notice that the key variable in our analyses – the R&D expenditure in MNE i in country j at time t RD_{ijt} – is always positive for the 2,583 observations in Table 3.1. However, in the econometric analysis of the determinants of the locations of R&D, in Section 4, we also add zero value observations of RD_{ijt} if employment in MNE i in country j at time t E_{ijt} is positive. Our rationale is that we expect the potential is high for such an MNE i to conduct R&D in country j, and thus, these zero observations contain valid and important information that should be exploited.

3.2 R&D expenditure and employment in Swedish MNEs at home and overseas

While MNEs used to carry out most of their R&D activities in their home countries (Patel and Pavitt 1991), in recent years, they have expanded their R&D expenditures in locations outside their home countries.[17] Figure 3.1 shows that Swedish MNEs are no exception in that respect.[18]

Figure 3.1 R&D expenditure shares of Swedish MNEs in Sweden, in high- and middle- and low-income countries. Percent.



Note: Table A1 in Appendix defines high- and middle and low-income countries.

Source: Swedish Agency for Growth Policy Analysis, Research and Development in Enterprises

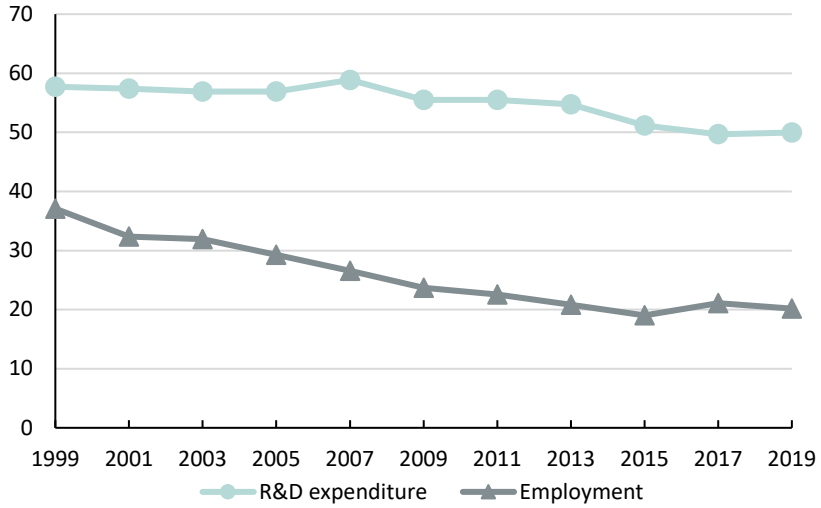
We observe that the home-country share of Swedish MNEs' R&D expenditure fell by almost 8 percentage points between 1999 and 2019, whereas the share in middle- and low-income countries increased by almost 11 percentage points. The R&D expenditure share in other high-income countries fell by approximately 3 percentage points. In other

[17] See, e.g., UNCTAD (2005), OECD (2008) and Dachs et al. (2014).

[18] In the description in Section 3.2 and the econometric analysis in Section 4, we present results for R&D expenditure during the period 1999 to 2019. The reasons are: (i) because one large Swedish MNE became foreign-owned and therefore dropped out of the sample and another important Swedish MNE divested between 1997 and 1999, quite substantial compositional effects arose, and (ii) in the econometric analysis we use lagged variables. The latter means that the first available observations of the dependent variable, RD_{ijt}, are from 1999.

words, the R&D expenditures in Swedish MNEs have shifted toward affiliates in middle- and low-income countries.

Figure 3.2 R&D expenditure and employment in parent companies in Sweden as a proportion of total R&D expenditure and employment in Swedish MNEs. Percent.



Source: Swedish Agency for Growth Policy Analysis, Research and Development in Enterprises and Swedish Groups with Affiliates Abroad

If we, as in Figure 3.2, compare the development of the home-country share of R&D expenditure in Swedish MNEs with their home-country share of employment, we find that the internationalization of R&D within MNEs seems to have been less pronounced than the internationalization of production and sales within MNEs. The decline in the home-country share of employment between 1999 and 2019 is just over 12 percentage points, which means that it is clearly larger than the decrease in the home-country share of R&D expenditure. Accordingly, Swedish MNEs appear to have been more inclined to retain R&D activities at home than production and sales activities.

Table 3.2 presents figures from 2019 and 1999 on absolute R&D expenditures and absolute employment, the number countries in which Swedish MNEs are present (have employment) and the number countries in which they conduct R&D.

Table 3.2 R&D expenditure, employment, and foreign affiliates of Swedish MNEs in Sweden, in high- and middle- and low-income countries

Swedish MNEs	Sweden			High-income			Middle- and low-income		
	1999	2019	Δ	1999	2019	Δ	1999	2019	Δ
R&D expenditure	36.7	46.5	9.8	25.0	33.7	8,7	1.8	12.8	11.0
Share (%)	57.7	50.0	−7.7	39.4	36.2	−3.2	2.9	13.8	10.9
Employment	156	105	−51	274	256	−18	112	265	153
Share (%)	28.9	16.8	−12.1	50.5	40.9	−9.6	20.7	42.3	21.6
Foreign affiliates									
a) Number of affiliates abroad									
R&D expenditure				106	160	54	30	109	79
Share (%)				77.9	59.5	−18.4	22.1	40.5	18.4
Employment				280	308	12	380	648	228
Share (%)				42.4	32.2	−10.2	57.6	67.8	10.2
b) Mean									
R&D expenditure				5	8	3	3	7	4
Employment				13	15	2	18	31	13

Notes: Foreign affiliates are the number of affiliates in different countries where a Swedish MNE has R&D expenditure or employment overseas. This means that even if an MNE has many affiliates in the same country abroad with R&D expenditure or employment, that is counted as only one foreign affiliate. Accordingly, our measure of foreign affiliates indicates to what extent an MNE has R&D expenditure or is established at all in various countries abroad. R&D expenditure is in billion SEK 2019 prices and employment in thousands.

Source: Swedish Agency for Growth Policy Analysis, R&D in International Groups and Swedish Enterprise Groups with Affiliates Abroad

To begin with, Table 3.2 shows that R&D expenditures are much more concentrated than employment in high-income countries (including Sweden); in 2019, the share of R&D expenditures in high-income countries was slightly more than 86 percent compared with the employment share, which was almost 58 percent. Moreover, we find that R&D expenditures have increased both in Sweden and abroad, in high-income countries and in middle- and low-income countries. In terms of percentage, the growth in the middle- and low-income countries is significantly higher than in Sweden and in the high-income countries. This is because, in 1999, the R&D expenditures of Swedish MNEs in middle- and low-income countries were very small.

Furthermore, we observe, in Table 3.2, similar shifts toward the middle- and low-income countries over the period in terms of considerably larger shares of R&D expenditures and employment. However, the difference is that in contrast to R&D expenditure, which has increased both in Sweden and in high-income countries, absolute employment has fallen in Sweden and in high-income countries. Additionally, we notice that the employment share in the middle- and low-income countries has grown faster between 1999 and 2019 (almost 22 percent) than the R&D expenditure share (nearly 11 percent).

In addition, Table 3.2 presents the number of countries in which each Swedish MNE has R&D activities and is operating, i.e., has employment. First, we find that Swedish MNEs were present in more countries in 2019 than in 1999. In particular, the foreign affiliates have increased in middle- and low-income countries. Second, we notice that Swedish

MNEs, on average, had R&D activities and employment in more countries in 2019 than in 1999. During the studied period, Swedish MNEs had R&D activities in 61 countries; 21 high-income countries and 40 middle- and low-income countries.[19] The corresponding figure for employment is 174 countries; 21 high-income countries and 153 middle- and low-income countries.

Table 3.3 tells us in which countries, in 2019, Swedish MNEs had the largest R&D expenditures and most employees in affiliates abroad. Additionally, as a comparison, Table 3.3 provides data for 1999.

Table 3.3 R&D expenditure and employment of Swedish MNEs in affiliates in different countries

Country	R&D expenditure		Country	Employment	
	2019	1999		2019	1999
United States	11,307	8,081	United States	69,902	84,241
	(23.1)	(30.1)		(13.4)	(21.9)
China	5,339	157	China	57,265	8,994
	(10.9)	(0.6)		(11.0)	(2.3)
Germany	4,002	3,191	India	38,351	9,814
	(8.2)	(11.9)		(7.4)	(2.5)
France	3,578	951	Germany	37,378	35,702
	(7.3)	(3.5)		(7.2)	(9.3)
Italy	2,687	1,622	France	25,678	23,675
	(5.5)	(6.0)		(4.9)	(6.1)
Canada	2,589	2,171	Brazil	21,873	15,211
	(5.3)	(8.1)		(4.2)	(3,9)
Switzerland	2,019	109	Italy	18,422	27,175
	(4.1)	(0.4)		(3.5)	(7.0)
India	1,777	11	United Kingdom	18,135	27,890
	(3.6)	(0.04)		(3.5)	(7.2)
Finland	1,534	877	Poland	17,044	4,686
	(3.1)	(3.3)		(3.3)	(1.2)
United Kingdom	1,357	1,472	Finland	11,341	7,773
	(2,9)	(5.5)		(2.2)	(2.0)
Poland	1,196	7	Belgium	10,059	9,087
	(2.4)	(0.03)		(1.9)	(2.4)
Belgium	1,175	724	Japan	10,031	2,697
	(2.4)	(2.7)		(1.9)	(0.7)
Korea	1,119	198	Canada	9,310	7,459
	(2.3)	(0.7)		(1,8)	(1.9)
Brazil	964	266	Korea	6,355	2,154
	(2.0)	(1.0)		(1.2)	(0.6)
Japan	940	761	Hungary	5,015	5,166
	(1.9)	(2.8)		(1.0)	(1.3)
Hungary	871	191	Switzerland	4,598	2,987
	(1.8)	(0.7)		(0.9)	(0.8)
Ireland	819	1,121	Ireland	1,565	2,423
	(1.7)	(4.2)		(0.3)	(0.6)

Notes: R&D expenditure is in 2019 prices and million SEK. Within parentheses are expenditure (employment) shares in total expenditure (employment) overseas.

[19] Table A1 in Appendix contains a list of the countries.

Source: Swedish Agency for Growth Policy Analysis, R&D in International Groups and Swedish Enterprise Groups with Affiliates Abroad

Concerning both R&D expenditure and employment, the United States is the most important country for Swedish MNEs. The significance is greater in regard to R&D expenditure, where almost a quarter takes place in the United States, while the corresponding figure for employment is approximately one-eighth. Otherwise, the most striking changes in Swedish MNEs' R&D expenditure we observed during the studied period were in China. After being a country, in 1999, where less than one percent of R&D was carried out, in 2019, China was second only to the United States as the country where Swedish MNEs conducted the most R&D (more than one-tenth). Other countries where we can see remarkable increases in R&D expenditures are Switzerland, India, Poland, and Korea. Last, we notice that the same countries that have high shares of R&D expenditures also have high employment shares.

In sum, the description in Section 3.2 shows that, since the late 1990s, R&D expenditures within Swedish MNEs have been more internationalized. However, production and other activities are still more internationally spread than R&D; even today, 50 percent of the R&D expenditures in the surveyed Swedish MNEs are carried out in Sweden, while the corresponding share in these MNEs for employment is barely 17 percent. This is an indication of home-country bias in the location of R&D. Moreover, although the largest increase in R&D expenditures has occurred in middle- and low-income countries, the R&D expenditures within Swedish MNEs remain, especially if we compare them with employment, concentrated in high-income countries.

Finally, a spectacular development in Swedish MNEs' R&D expenditures in China has taken place during the studied period. After being a country in which almost no R&D was conducted, in 2019, China was the country where, other than the United States, the R&D expenditure within Swedish MNEs was the largest.

We will now proceed and econometrically analyze the determinants of the location of R&D expenditures within Swedish MNEs.

4. Econometric analysis

4.1 Econometric specification

The purpose of the econometric analysis is to explain the localization pattern of R&D within MNEs *i* across countries *j* at time *t* RD_{ijt}. Our estimated model is based on the discussion and hypotheses we put forward in Section 2 on what factors foster or hamper investments in R&D in a country.

To analyze factors that may affect the localization of R&D in Swedish MNEs abroad and in Sweden, we estimate the following model:

$$RD_{ijt} = exp\left[\beta_1 \ln GDP_{jt-1} + \beta_2 \ln DIST_j + \sum_k \beta_k D_k\right] \times$$
$$exp\left[\beta_3 ES_{ijt-1} + \beta_4 EXP_{ijt-1} + \beta_5 RDL_{it} + \beta_6 (RD/GDP)_{jt-1} + \beta_7 TERC_{jt-1}\right] \times$$
$$exp\left[\beta_8 IPR_{jt-1} + \beta_9 \ln WAGE_{jt-1} + \beta_{10} TAX_{jt-1} + \alpha_i + \alpha_t + \varepsilon_{ijt}\right] + \varepsilon_{ijt} \quad (1)$$

Note that the explanatory variables are lagged with respect to the dependent variable to account for the fact that investment decisions are lagged in time. This is an attempt to at least try to avoid possible endogeneity.

In our econometric specifications, we start from a gravity model approach and regress R&D expenditure in Swedish MNEs *i* in countries *j* at time *t* RD_{ijt} on $\ln GDP_{jt-1}$ in countries *j* at time *t–1* and geographic distance from Sweden to countries *j* $\ln DIST_j$. In a panel data study such as ours, the GDP variable also captures income growth, which is generally a key driver of attracting FDI (Blonigen 2005). Moreover, R&D investments often follow FDI in production and sales; they are extensions of such activities abroad.

To examine whether cultural and linguistic barriers and similar institutions affect the locational choice of R&D, we add a few dummy variables D_k. One is a dummy variable for English-speaking countries, and another is for countries that became members of the EU in 1995 or earlier, *k* is *Eng* or *EU14* (not Sweden).

Furthermore, we include a dummy variable for Sweden – *k* is *Swe* – to investigate if Swedish MNEs, other things remaining equal, are more inclined to locate their R&D in Sweden (*home-country bias*), and another dummy variable for Sweden during the latter part of the studied period (2009 to 2019) to examine whether the home-country bias has changed over time, i.e., *k* is *Swe0919*.

In our estimated model, we also add some MNE-location country-specific variables, such as MNE *i*'s share of employment in country *j,* ES_{ijt-1}, and the number of years an MNE *i* has had employees in country *j*, EXP_{ijt-1}. ES_{ijt-1} is an indicator of the importance of country *j* as a market for MNE *i,* and EXP_{ijt-1} is an indicator of the experience of the market MNE *i* has acquired from being active in country *j*.

RDL_{it} is R&D expenditure relative to employment (non-researchers)[20] of MNE *i* at time *t* and controls for heterogeneities among MNEs in R&D intensities and changes in R&D intensities over time.

Finally, other country variables aimed at capturing attracting (pull) and repelling (push) factors are introduced into the model. The pull factors are the share of the economically active population with completed tertiary education $TERC_{jt-1}$ as a measure of the relative endowment of skilled labor and total R&D expenditure as a proportion of GDP $(RD/GDP)_{jt-1}$ as an indicator of the technological level and innovative activity in country *j*. Closely related to the R&D intensity in country *j*, and an alternative variable, is the number of researchers per thousand employed REM_{jt-1}.

Another attracting factor is the sufficiently good protection of intellectual property rights. IPR_{jt-1} is a variable that aims to measure the strength of patent protection in country *j;* the larger IPR_{jt-1} is, the more strongly the patent rights are protected. The presumed repelling (push) factors are high wage costs of skilled labor, ln $WAGE_{jt-1}$, which reflects the earnings of electrical engineers, and high corporate taxes, TAX_{jt-1} .[21]

Table A2 in the Appendix gives a complete description of the variables included in the econometric model and sources of data. Moreover, our econometric specifications contain MNE specific fixed effects, α_i, time dummies, α_t, and an error term, ε_{ijt}.

Before we, in Section 4.2, present the econometric results from the estimations of various specifications of our econometric model in Equation (1), we show, in Table 4.1, the summary statistics of the country variables (last year available) in which Swedish MNEs have located R&D activities and for which data are available. In addition to standard summary statistics of variables, we also separately present the data for Sweden and the rank of Sweden among the available countries.

Table 4.1 Summary statistics of country variables

Variable	Mean	Standard deviation	Max	Min	Number of countries	Sweden
		Attracting (pull) factors				
GDP	1,831	3,855	21,229	20	60	533 (31)
$TERC$	19.6	9.5	46.9	2.3	61	26.6 (16)
$RDGDP$	1.55	1.10	4.94	0.13	61	3.31 (5)
REM	7.9	3.8	15.2	1.0	49	14.7 (3)
IPR	4.08	0.52	5.00	2.44	55	4.54 (8)
		Repelling (push) factors				
$DIST$	4,704	4,395	17,739	252*	61	252 (1)
$WAGE$	38.0	24.6	116.5	4.2	52	54.2 (15)
$ATAX$	21.9	5.9	34.9	8.2	44	19.4 (26)
$MTAX$	14.3	7.2	30.9	2.8	44	13.0 (24)

Notes: *Internal distance of Sweden. Gross domestic product *GDP* is in billion USD 2017 prices, and distance *DIST* is in kilometers. The share of the population with completed tertiary education $TERC$, R&D intensity *RD/GDP*, and corporate tax rates ($ATAX$ average and $MTAX$ marginal) are all in percentage. The number of researchers *REM* are per thousand employed, and the earnings of

[20] This is number of employees minus the number of yearly full-time equivalents in R&D.

[21] We have access to two measures of corporate tax: the effective average tax rate, $ATAX_{jt-1}$, and the effective marginal tax, $MTAX_{jt-1}$.

electrical engineers *WAGE* are in thousands USD. The international patent protection rate *IPR* is an indicator variable between 1 and 5, where 5 means strong patent protection. The number of countries includes countries for which data on the variable are available. Notice that this does not mean that there are data for the country every year in the panel. For Sweden, we report the figure of the variable for the last year in the panel, and within the parentheses, the rank Sweden had that year.

In Table 4.1, we observe, among the attracting factors, that the variable that indicates the technological level in a country – the R&D intensity in country j – is accessible for all countries where Swedish MNEs have had R&D operations but not for all years in the panel. The R&D intensity $RDGDP$ is high in Sweden; in 2019, Sweden is ranked fifth, after Israel, Korea, Switzerland, and Taiwan, with an R&D intensity clearly above the average. For the related variable, the relative endowment of researchers *REM* Sweden is also highly ranked. For the relative endowment of skilled labor *TERC* Sweden is lower ranked, however, well above the average among the countries included. The indicator of international patent protection *IPR* is available for almost all countries in the panel, but unfortunately only until 2015. As in most other high-income countries, international patent protection is strong in Sweden.

Regarding the repelling factors, data on earnings for engineers *WAGE* are available in most countries, at least at the end of the studied period. For *IPR*, there are no data on *WAGE* after 2015. Skilled labor wages in Sweden are at the higher end among all investment countries but somewhere in the middle among the high-income investment countries. For corporate taxes, *ATAX* and *MTAX*, there are observations for fewer countries. From Table 3.5, we note that the corporate tax in Sweden is not very high but rather at an average level among the countries in the analysis.

4.2 Estimation method and empirical results

To handle heteroscedasticity and allow for the convenient incorporation of zeros, we estimate the model in equation (1) with a Poisson pseudo maximum-likelihood (PPML) method.[22] Our dependent variable has a significant number of zero observations (59 percent). This is because we include zero observations of RD_{ijt} for countries j if an MNE i has employment in country j. The reason is that if MNE i has employment in country j, the probability is not negligible that it will, in the future, also have R&D in country j.

Table 4.2 presents the main results from our estimations.[23]

[22] We prefer this approach before a previously commonly used method to include zero observations in log-linear models, i.e., to set $\ln(RD_{ijt}+1)$ if $RD_{ijt}=0$.

[23] Appendix Tables A4 to A7 contain additional results and provide some robustness checks. In Table A4, we show the OLS estimate of the specifications in Table 4.2, in Table A5, we allow the number of observations to vary among the specifications, and in Table A6, we present some results from alternative specifications. Table A7 shows results from the same specifications as in Table 4.2 estimated on the nine Swedish MNEs that are in the panel during the whole period of study (the balanced sample). By using such a constraint, the number of observations drops 42 percent. Despite this, the results still appear to be fairly robust. However, the OLS estimates in Table A5 seem to be less robust, which we obtain using the same specifications and observations as in Table 4.2.

Table 4.2 Determinants of the R&D location. Dependent variable: R&D expenditure in Swedish MNEs i in country j at time t, RD_{ijt}

	(1) Poisson	(2) Poisson	(3) Poisson	(4) Poisson	(5) Poisson	(6) Poisson
$ln\ GDP_{jt-1}$	0.869	0.801	0.647	0.629	0.537	0.450
	(14.04)	(8.95)	(12.27)	(10.37)	(9.78)	(11.50)
$ln\ DIST_j$	–0.333	–0.135	–0.159	–0.084	–0.083	–0.039
	(–4.00)	(–1.13)	(–1.41)	(–0.69)	(–0.61)	(–0.36)
D_{Swe}	4.061	4.845	3.126	3.144	2.376	2.491
	(16.69)	(10.47)	(6.49)	(6.25)	(4.37)	(5.19)
$D_{Swe0919}$	–0.102	–0.143	0.646	0.604	0.861	0.696
	(–0.77)	(–1.06)	(1.97)	(1.68)	(2.71)	(2.17)
D_{EU14}		0.618	0.628	0.753	0.649	0.277
		(2.52)	(2.80)	(2.94)	(2.21)	(1.12)
$D_{English}$		0.456	0.441	0.126	0.456	0.328
		(1.55)	(1.86)	(0.36)	(1.58)	(1.04)
ES_{ijt-1}			4.532	4.676	4.543	4.475
			(6.05)	(6.78)	(6.86)	(7.02)
EXP_{ijt-1}			0.103	0.092	0.062	0.050
			(1.19)	(1.11)	(0.85)	(0.67)
RDL_{it}			–0.185	–0.192	–0.166	–0.180
			(–1.30)	(–1.39)	(–1.21)	(–1.27)
$TERC_{jt-1}$				0.032	0.004	–0.013
				(3.42)	(0.63)	(–1.47)
$RDGDP_{jt-1}$					0.453	0.215
					(4.27)	(2.03)
IPR_{jt-1}						1.118
						(3.86)
$\ln WAGE_{jt-1}$						0.100
						(0.37)
$ATAX_{jt-1}$						–0.236
						(–0.14)
No of obs	4,490	4,490	4,490	4,490	4,490	4,490

Notes: The reported z-values in parentheses are based on robust standard errors using the formula presented in Wooldridge (1999).

In Table 4.2 specification (1), we start from a standard gravity model, including GDP in country j $ln\ GDP_{jt-1}$ and distance from Sweden to the destination country j $ln\ DIST_j$ and then we add two dummy variables, one for Sweden D_{Swe} and the other $D_{Swe0919}$ for Sweden during the latter part of the studied period, i.e., 2009 to 2019. The first allows for home-country bias, and the second allows for whether the home-country bias has changed from the beginning to the end of the period.

The coefficient on $ln\ GDP_{jt}$ is clearly significant in specification (1) and in all other specifications in Table 4.2. Swedish MNEs are thus more prone to invest in R&D in large, fast-growing economies. However, the size of the coefficient decreases as we include more variables in the estimated model.

The coefficient on $ln\ DIST_j$ is negative, as it usually is in gravity equations.[24] Interestingly, already in specification (2), when we add a dummy for long-term members of the EU D_{EU14} and a dummy for English-speaking countries $D_{English}$, the significance of $ln\ DIST_j$ disappears, and it continues to be insignificant in the rest of the specifications.[25] This indicates that distance is less hampering of R&D investment than of trade flows and of FDI in general.

In specification (1), the Sweden dummy D_{Swe} is strongly significant, which highlights a considerable home-country bias effect, whereas the Sweden dummy for the latter part of the period $D_{Swe0919}$ is insignificant. We will return to these dummy variables later.

The coefficient on the dummy D_{EU14}, which is supposed to capture similarities in institutions, is significant in all specifications except the last one (specification 6),[26] while the coefficient on the dummy $D_{English}$ is significant only at the 10 percent level in one of the estimated models (specification 3). In other words, we find some support for the hypothesis that the similarity of institutions in different countries facilitates investment in R&D, while being an English-speaking country does not have a decisive significance.

In specification (3), we introduce our enterprise-specific variables. We control for an MNE's R&D intensity RDL_{it}, which never appears to be significant.[27] We include variables that aim to capture the importance a country has as a market for an MNE ES_{ijt-1} and the experience an MNE has in a market EXP_{ijt-1}. ES_{ijt-1} is strongly significant in all specifications, whereas EXP_{ijt-1} is never significant.[28] This means that if an MNE has a substantial and increasing share of its activities in a country, it also has a large and growing amount of R&D in that country. Moreover, since we include zero observations of R&D if an MNE has employment in a country, we also capture the cases when an MNE is expanding its employment share in a country, as Swedish MNEs have done in many middle- and low-income countries, and eventually begins to invest in R&D in the country.

In specifications (4) and (5), we start introducing our country variables. In specification (4), we add our measure of the relative endowment of skilled labor in a country $TERC_{jt-1}$, which is clearly significant. However, in specification (5), when we include the variable that is supposed to be an indicator of the technological level and innovative activity in a country $RDGDP_{jt-1}$, that variable is strongly significant,[29] but now the coefficient on

[24] An example is Kleinert and Toubal (2010). They provide theoretical underpinnings for the gravity equation applied to an analysis of sales of foreign affiliates of MNEs. They estimate various specifications of such models for a large sample of country pairs using PPML and their estimates on distance are always negative and significant.

[25] In Table A4 in the Appendix, where we present OLS estimates of the same specifications as in Table 4.2, the negative effect from distance is larger and significant in all specifications.

[26] Most likely, the reason is multicollinearity. By introducing the variables IPR_{jt-1} and $\ln WAGE_{jt-1}$, which are strongly correlated with the dummy variable D_{EU14} (see the correlation matrix in Table A3 in the Appendix), the coefficient on D_{EU14} decreases and becomes insignificant.

[27] One striking difference between the results for the unbalanced sample in Table 4.2 and the balanced sample in Table A7 is the estimates on the MNEs' R&D intensities, which are positive and significant (as expected) in all specifications in Table A7.

[28] Even if we exclude ES_{ijt-1}, the coefficient on EXP_{ijt-1} is still insignificant (see Table A6 specification (1) in the Appendix).

[29] An alternative variable to $RDGDP_{jt-1}$ is the number of researchers per thousand employed REM_{jt-1}. If we replace $RDGDP_{jt-1}$ with REM_{jt-1}, the estimate is positive, as expected, and significant at the 10 percent level (Table A6 specification (2) in the Appendix)

$TERC_{jt-1}$ turns out to be insignificant. This illustrates a problem with some country variables, namely, multicollinearity; they are strongly correlated (see the correlation matrix in Table A3 in the Appendix).[30]

Finally, in specification (6) – our preferred specification – we add a few more country variables: the indicator of international patent protection IPR_{jt-1}, which is highly significant, and the skilled labor wage $\ln WAGE_{jt-1}$ and average corporate tax rate $ATAX_{jt-1}$, which are both insignificant. In other words, protection of intellectual property rights in the investment country seems to be important for Swedish MNEs, while unlike for FDI in general, the propensity to invest in R&D is not affected by high corporate taxes.[31] A better quality of skilled workers may be reflected in higher wages, which can explain why the higher costs do not seem to affect the willingness to invest in R&D.

Let us now return to the Swedish dummy for the later period $D_{Swe0919}$, which is significant in specification (3), (5) and (6) and significant at the 10 percent level in specification (4). From specification (3) on, the variable on the share of an MNE's employment in country ES_{ijt-1} is included in the estimated equation, and for which the estimated coefficient is highly significant.[32] From Table 3.3, we can see that the share of employment in affiliates abroad has increased, especially in middle- and low-income countries. This should also have meant a higher share of R&D expenditure overseas, and this is in fact the case. However, the increase in the share of R&D expenditure overseas has been less pronounced than the increase in the share of employment, and this may be due to a reinforced home-biased effect; $D_{Swe0919}$ is significantly positive.[33] This suggests that Sweden as an investment country for R&D has not deteriorated but rather improved.

[30] The reported correlations and variance inflation factors VIF in Table A3 indicate that the problems are largest for the variables $RDGDP$, IPR, and $\ln WAGE$

[31] Meta studies on the relationships between corporate taxes and FDI, such as Feld and Heckemeyer (2011) and de Mooij and Ederveen (2008), indicate a negative correlation; a one percentage point increase in the host country's corporate tax is associated with a drop in aggregate FDI of 2.5 to 3.1 percent. Davies et al. (2021) find that the deterring impact of corporate taxes on FDI in general operates primarily on the extensive margin, i.e., that the average tax rate $ATAX$ is of more importance than the marginal tax rate $MTAX$. As an alternative, in Table A6 specification (3), we replace $ATAX$ with $MTAX$. However, the coefficient on corporate tax rate is still insignificant.

[32] If we exclude ES_{ijt-1} from specification (3), $D_{Swe0919}$ becomes insignificant (See Table A5 specification (1) in the Appendix).

[33] Eliasson et al. (2022), who also use employment data on Swedish MNEs in their parents in Sweden and their affiliates abroad, find that offshoring within Swedish MNEs – increased employment shares in affiliates overseas – are related to skill upgrading in the parents at home. The result is consistent with the observation that Swedish MNEs are more inclined to offshore production and sales, while keeping the more skill-intensive parts of the value chain, such as R&D activities, in Sweden.

5. Concluding remarks

The R&D expenditures in Swedish MNEs have increased both among the parents at home in Sweden and their affiliates abroad. While R&D expenditures, in contrast to employment in Swedish MNEs, still are concentrated in high-income countries, the growth in R&D expenditure has been larger in middle- and low-income countries, particularly in China. China is now the country, other than the United States, in which Swedish MNEs conduct the most foreign R&D.

However, the internationalization of R&D within the Swedish MNE has not been as sizeable as for other parts of the value chain. As a comparison, we observe that half of the R&D expenditure in Swedish MNEs is carried out in Sweden, whereas barely 17 percent of their employment is in Sweden.

From the econometric analysis, we find that large, fast-growing countries attract R&D from Swedish MNEs. Other important pull factors on investment in R&D appear to be a high technological level in the investment country, a sufficient supply of qualified and well-educated workers, and advantageous institutions, e.g., satisfactory protection of intellectual property rights and a well-functioning national system of innovation. We interpret the significance of the technological level as support for knowledge sourcing (*asset augmenting*) being a salient motive for investing in R&D in other countries.

In addition, our results indicate that high wages of skilled workers (engineers) and high corporate taxes do not obviously deter investment in R&D in a country, high wages because such might also include a quality component and corporate taxes because these may be less important for investment decisions in R&D than for FDI in general. Another interesting finding is that, unlike studies of FDI in general based on a gravity approach, the distance to the host country does not seem to impede R&D investments.

A caveat is a strong correlation between some of the country variables in the econometric analysis. This entails that it can be hard to identify significant relationships or that the results are not always robust.

If Sweden is compared with other investment countries in the analysis, we can see that the proportion of R&D expenditure of GDP and the number of researchers per 1,000 employed are high, which suggests that the technological level is high and that the innovation activities are large. As in many other high-income countries, the protection of patent rights in Sweden is strong, and compared with other high-income countries, skilled labor wages and corporate taxes are not particularly high in Sweden.

The importance of a country as a market for an MNE – the employment share in the country – is a significant determinant of whether Swedish MNEs locate their R&D in a country and the scope of their R&D activities in the country. This is consistent with the idea that in important markets, MNEs tend to adapt their products to local preferences and requirements (*asset exploiting*).

Similar institutions seem to be a relevant factor for the locational choice of R&D, while linguistic barriers are to a much lesser extent.

Finally, a finding consistent with the previous literature is that the localization of R&D within Swedish MNEs is home-market biased. However, more interestingly the home bias within Swedish MNEs turns out to have increased over the studied period. An interpretation of this is that Sweden as an investment country for R&D has not deteriorated over time; rather, the opposite has occurred. However, this is not something to take for granted in the future.

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Appendix

Table A1 High- and middle- and low-income countries

High-income	Middle- and low-income	
Australia	Argentina	Morocco
Austria	Brazil	New Zealand
Belgium	Bulgaria	Panama
Canada	Chile	Peru
Denmark	China	Poland
Finland	Colombia	Portugal
France	Croatia	Romania
Germany	Czechia	Russia
Hong Kong	Egypt	Serbia
Iceland	Estonia	Slovakia
Ireland	Hungary	Slovenia
Italy	India	South Africa
Japan	Indonesia	Spain
Luxembourg	Iran	Sri Lanka
Netherlands	Israel	Taiwan
Norway	Korea	Thailand
Singapore	Latvia	Turkey
Sweden	Lithuania	Ukraine
Switzerland	Malaysia	United Arab Emirates
United Kingdom	Malta	
United States	Mexico	

Notes: We define high-income countries as countries with GNI per capita larger 65 percent of Sweden's over the studied period.

Table A2 Description of variables and data sources

Variable	Description	Source	Type
Dependent variable			
R&D in MNE *i* in country *j* at time *t*, RD_{ijt}	R&D expenditure every two years in Sweden and abroad, million SEK, 2019 prices	Growth Analysis	MNE – Location country
Gravity variables			
GDP in country *j* at time *t-1*, GDP_{jt-1}	GDP in USD PPP 2017 prices	World Bank	Location country
Distance between Sweden and country *j*, $DIST_j$	Geographic distance between Stockholm and the capital of country *j*	CEPII. The data is described in Mayer and Zignago (2011) and is downloadable*.	Location country
MNE variables			
Share of employment in MNE *i* in country *j* at time *t-1*, ES_{ijt-1}	Employment share in affiliates of MNE *i* in country *j*	Growth Analysis	MNE – Location country
MNE *i*'s experience of country *j* at time *t-1*, EXP_{ijt-1}	Number of years MNE *i* has been operative in country *j*	Growth Analysis	MNE – Location country
R&D intensity in MNE *i* at time *t*, RDL_{it}	R&D expenditure relative to employment (non-researchers) in MNE *i*	Growth Analysis	MNE
Country variables			
Relative endowments of skilled labor at time *t-1*, $TERC_{jt-1}$	Share of population 25-64 years with a completed tertiary education	Barro and Lee (2013)	Location country
R&D intensity in country *j* at time *t-1*, $(RD/GDP)_{jt-1}$	Total expenditure on R&D in the business sector in a country as a proportion of the country's GDP	UNESCO Institute for Statistics and OECD Science & Technology Indicators	Location country
Relative endowments of researchers at time *t-1*, REM_{jt-1}	Number of researchers per thousand employed	UNESCO Institute for Statistics and OECD Science & Technology Indicators	Location country
Skilled labor wages in country *j* at time *t-1*, $WAGE_{jt-1}$	Earnings (gross USD) of electrical engineers. Every three years from 1994 to 2015.	UBS Prices and Earnings	Location country
Corporate tax rate in country *j* at time *t-1*, TAX_{jt-1}	Two measures of the corporate tax rate, the effective average tax rate $ATAX$ and the effective marginal tax rate $MTAX$	CBT Tax Database. Downloadable**	Location country

Table A2 Continued

Variable	Description	Source	Type
International patent protection in country *j* at time *t-1*, IPR_{jt-1}	The variable aims to measure the strength of patent protection. The variable is an index based on five underlying factors. Assumes values on a scale from 1 to 5, where 5 entails that the patent protection is strong, while 1 implies that the protection is weak.	Ginarte and Park (1997) and Park (2008)	Location country

* http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=6
** https://oxfordtax.sbs.ox.ac.uk/cbt-tax-database

Table A3 Correlation matrix of location selected country variables in the regression analysis

	$\ln GDP$	$\ln DIST$	D_{EU14}	D_{Eng}	$TERC$	$RDGDP$	IPR	$\ln WAGE$	$ATAX$	VIF
$\ln GDP$										1,67
$\ln DIST$	0,41									2,02
D_{EU14}	−0,05	−0,36								1,73
D_{Eng}	0,26	0,36	−0,08							1,40
$TERC$	0,08	−0,11	0,00	0,31						1,79
$RDGDP$	0,09	−0,31	0,22	−0,02	0,51					2,57
IPR	0,06	−0,34	0,49	0,05	0,42	0,62				2,69
$\ln WAGE$	−0,01	−0,16	0,42	0,10	0,38	0,64	0,69			2,74
$ATAX$	0,48	0,31	0,20	0,14	−0,09	0,16	0,12	0,26		1,73

Notes: The variance inflation factor is defined as $VIF_j = 1/(1 - R_j^2)$ where R_j^2 is the R^2-value obtained when regressing the j^{th} country variable on the remaining country variables in the matrix.

Table A4 Determinants of the R&D location. OLS estimates.

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
$ln\ GDP_{jt}$	0.755	0.692	0.451	0.446	0.409	0.421
	(9.64)	(9.13)	(6.32)	(6.38)	(6.29)	(6.15)
$ln\ DIST_j$	–0.397	–0.319	–0.222	–0.205	–0.207	–0.209
	(–6.27)	(–4.90)	(–3.37)	(–2.99)	(–3.07)	(–3.28)
D_{Swe}	4.594	5.161	2.333	2.323	1.612	1.729
	(10.17)	(11.78)	(4.97)	(4.92)	(3.31)	(3.63)
$D_{Swe0919}$	–0.172	–0.225	0.796	0.794	1.021	0.958
	(–0.63)	(–0.85)	(2.09)	(2.08)	(2.69)	(2.58)
D_{EU14}		0.677	0.618	0.626	0.439	0.227
		(4.59)	(4.31)	(4.39)	(3.06)	(1.61)
D_{Eng}		0.703	0.499	0.437	0.610	0.567
		(3.69)	(2.63)	(2.47)	(3.12)	(2.97)
ES_{ijt-1}			11.057	11.082	10.776	10.51
			(5.44)	(5.43)	(5.55)	(5.65)
EXP_{ijt-1}			0.051	0.050	0.031	0.023
			(2.78)	(2.77)	(1.65)	(1.15)
RDL_{it}			1.238	1.236	1.271	1.259
			(1.07)	(1.07)	(1.09)	(1.08)
$TERC_{jt-1}$				0.007	–0.017	–0.021
				(1.04)	(–2.18)	(–2.68)
$RDGDP_{jt-1}$					0.416	0.272
					(5.47)	(–2.68)
IPR_{jt-1}						0.458
						(3.09)
$\ln WAGE_{jt-1}$						0.120
						(1.31)
$ATAX_{jt-1}$						0.008
						(0.01)
No of obs	4,490	4,490	4,490	4,490	4,490	4,490

Notes: If $RD_{ijt} = 0$, we are setting $\ln(RD_{ijt} + 1)$. The reported *t*-values in parentheses are based on robust standard errors.

Table A5 Determinants of the R&D location. Unrestricted samples.

	(1) Poisson	(2) Poisson	(3) Poisson	(4) Poisson	(5) Poisson	(6) Poisson
$ln\ GDP_{jt}$	1.021	0.942	0.799	0.743	0.640	0.481
	(23.54)	(15.11)	(16.52)	(15.80)	(14.80)	(12.59)
$ln\ DIST_j$	–0.517	–0.321	–0.328	–0.204	–0.170	–0.115
	(–6.99)	(–2.47)	(–2.75)	(–1.48)	(–1.12)	(–1.06)
D_{Swe}	4.008	4.776	3.222	3.134	2.371	2.338
	(16.35)	(10.23)	(7.03)	(6.63)	(4.61)	(4.88)
$D_{Swe0919}$	–0.115	–0.148	0.540	0.617	0.890	0.732
	(–0.79)	(–0.99)	(1.69)	(1.76)	(2.85)	(2.21)
D_{EU14}		0.632	0.627	0.824	0.710	0.257
		(2.64)	(2.83)	(3.49)	(2.58)	(1.06)
D_{Eng}		0.493	0.456	0.120	0.443	0.310
		(1.75)	(2.02)	(0.32)	(1.41)	(0.96)
ES_{ijt-1}			3.902	4.647	4.486	4.507
			(4.62)	(7.06)	(6.99)	(7.08)
EXP_{ijt-1}			0.101	0.111	0.074	0.040
			(1.33)	(1.24)	(0.94)	(0.53)
RDL_{it}			–0.130	–0.198	–0.167	–0.178
			(–0.73)	(–1.42)	(–1.19)	(–1.21)
$TERC_{jt-1}$				0.035	0.004	–0.011
				(3.52)	(0.51)	(–1.30)
$RDGDP_{jt-1}$					0.486	0.223
					(4.83)	(2.15)
IPR_{jt-1}						1.048
						(3.62)
$\ln WAGE_{jt-1}$						0.089
						(0.34)
$ATAX_{jt-1}$						0.038
						(0.02)
No of obs	8,231	8,231	6,798	6,006	5,859	4,653

Notes: Unlike the results presented in Table 4.2, we allow the number of observations to vary among the specifications. The reported z-values in parentheses are based on robust standard errors using the formula presented in Wooldridge (1999).

Table A6 Determinants of the R&D location. Alternative specifications.

	(1) Poisson	(2) Poisson	(3) Poisson
$ln\ GDP_{jt}$	0.769	0.659	0.457
	(10.41)	(8.37)	(8.66)
$ln\ DIST_j$	–0.135	–0.050	–0.039
	(–1.15)	(–0.37)	(–0.29)
D_{Swe}	4.721	2.813	2.455
	(12.45)	(6.63)	(4.68)
$D_{Swe0919}$	–0.193	0.668	0.707
	(–1.36)	(1.97)	(2.21)
D_{EU14}	0.556	0.598	0.257
	(2.67)	(2.75)	(0.94)
D_{Eng}	0.438	0.212	0.356
	(1.45)	(0.73)	(1.00)
ES_{ijt-1}		4.734	4.460
		(6.77)	(7.16)
EXP_{ijt-1}	0.153	0.072	0.050
	(1.44)	(0.98)	(0.68)
RDL_{it}	0.187	–0.174	–0.180
	(0.97)	(–1.28)	(–1.26)
$TERC_{jt-1}$		0.006	−0.014
		(0.66)	(–1.49)
REM_{jt-1}		0.092	
		(1.71)	
$RDGDP_{jt-1}$			0.238
			(2.65)
IPR_{jt-1}			1.085
			(3.92)
$\ln WAGE_{jt-1}$			0.124
			(0.40)
$MTAX_{jt-1}$			–0.993
			(–0.98)
No of obs	4,490	4,490	4,490

Notes: The reported z-values in parentheses are based on robust standard errors using the formula presented in Wooldridge (1999).

Table A7 Determinants of the R&D location. Balanced samples.

	(1) Poisson	(2) Poisson	(3) Poisson	(4) Poisson	(5) Poisson	(6) Poisson
$ln\ GDP_{jt-1}$	0.882	0.804	0.664	0.646	0.566	0.466
	(12.69)	(7.85)	(12.07)	(10.20)	(11.18)	(11.73)
$ln\ DIST_j$	–0.348	–0.094	–0.125	–0.069	–0.047	0.016
	(–3.99)	(–0.70)	(–0.97)	(-0.51)	(–0.29)	(0.12)
D_{Swe}	4.062	5.067	3.116	3.112	2.535	2.716
	(16.52)	(9.09)	(7.37)	(6.78)	(5.40)	(6.95)
$D_{Swe0919}$	0.057	0.009	0.853	0.825	1.037	0.865
	(1.01)	(0.13)	(3.32)	(2.90)	(4.31)	(3.69)
D_{EU14}		0.769	0.709	0.798	0.752	0.453
		(2.39)	(2.53)	(2.66)	(2.17)	(1.43)
$D_{English}$		0.526	0.446	0.214	0.470	0.391
		(1.79)	(1.58)	(0.62)	(1.55)	(1.29)
ES_{ijt-1}			4.865	4.968	4.887	4.733
			(5.25)	(5.82)	(5.91)	(5.97)
EXP_{ijt-1}			0.322	0.307	0.244	0.235
			(1.74)	(1.60)	(1.68)	(1.73)
RDL_{it}			1.849	1.782	1.861	1.907
			(3.04)	(2.98)	(3.14)	(3.09)
$TERC_{jt-1}$				0.024	0.003	–0.011
				(4.01)	(0.44)	(–1.30)
$RDGDP_{jt-1}$					0.362	0.158
					(3.85)	(1.34)
IPR_{jt-1}						1.306
						(6.93)
$\ln WAGE_{jt-1}$						–0.116
						(–0.79)
$ATAX_{jt-1}$						–0.400
						(–0.22)
N	2,612	2,612	2,612	2,612	2,612	2,612

Notes: The reported *z*-values in parentheses are based on robust standard errors using the formula presented in Wooldridge (1999).

På vilket sätt statens insatser bidrar till svensk tillväxt och näringslivsutveckling står i fokus för våra rapporter.

Läs mer om vilka vi är och vad nyttan med det vi gör är på www.tillvaxtanalys.se. Du kan även följa oss på LinkedIn och YouTube.

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Varmt välkommen att kontakta oss!

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