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R&D Employment and Transmission in Trade and MNE Networks: Evidence from a R&D Tax Reform ^{*}

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Abstract

We combine R&D survey data, Swedish and Danish register data, MNE group information, firm-to-firm trade linkages, and a plausibly exogenous policy shock that reduces firms' employment related R&D expenditures to provide evidence for the allocation of R&D activities among Swedish-Danish trade and MNE partners. We first show that Swedish firms increased their R&D employment in response to the introduction of an R&D related tax deduction. We then show that the R&D tax reform leads to a fall in R&D employment among Danish MNE partners, but an increase among Danish trade partners. We conclude that R&D policies increase global research activities within trade networks, but substitution across affiliates dampens the reform's effect on research activity within MNE networks.

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1 Introduction

A substantial amount of research highlights the potential benefits of knowledge spillovers due to Multinational Enterprises (MNEs) and international trade for productivity and economic growth (Keller, 2022). A primary source of knowledge is countries' own as well as foreign R&D (Coe and Helpman, 1995; Keller, 2000; Keller, 2002). However, little empirical evidence exists for R&D activity within international MNE and trade networks, especially in response to well-defined policy shocks. In this paper, we combine R&D survey data, Swedish register data, Danish register data, MNE group information, firm-to-firm trade linkages, and a plausibly exogenous employment related R&D policy shock to provide evidence for the allocation of R&D activities among Swedish-Danish trade and MNE partners.

Our empirical approach proceeds in several steps. First, we match Swedish and Danish firms in our register data with detailed MNE membership information. In addition, we employ unique and novel data on firm-to-firm trade transactions between Danish and Swedish firms. Jointly, these data sources allow us to identify existing Danish-Swedish MNE and trade network members combined with their members' register data. Combining Danish and Swedish register data allows us to examine R&D activity based on employment related R&D expenditures, which is the main target of recent Swedish R&D policies.

Second, we take advantage of a new Swedish R&D related tax reform as a source of exogenous variation to examine Swedish firm's innovation activities. The reform, introduced in 2014, allows Swedish firms to deduct employment related R&D expenses but only up to a limit. Consequently, we apply a difference-in-difference identification strategy similar to Bøler et al. (2015). In particular, we compare employment related R&D expenditures across Swedish firms whose marginal R&D expenses are expected to decrease as a consequence of the reform (firms expected to be below the deduction limit) to firms whose marginal costs are not affected (firms expected to be above the deduction limit) before and after 2014.

Third, we extend the difference-in-difference approach to Danish firms. In particular, focusing on Danish firms with trade and MNE linkages in Sweden, we ask if those Danish

firms linked to Swedish firms whose marginal costs related to R&D activity likely decreased as a consequence of the Swedish reform see a change in their own R&D activity compared to those Danish firms who are linked to Swedish firms that are not expected to be affected by the R&D reform. While this approach provides insight into whether Danish firms are affected by the Swedish policy through MNE and trade linkages, it does not provide actual substitution elasticities between R&D workers in Swedish and Danish firms. We address this in our fourth and final identification approach.

Fourth, following an instrumental variable approach similar to Kovak et al. (2021), we estimate the elasticity of Danish firms' R&D activity with respect to their trade and MNE partners R&D activity in Sweden.¹ We start by predicting Swedish firms' R&D activity based on the R&D reform. Then, we use predicted R&D activity in Sweden as an instrument to examine how Danish firms' employment related R&D expenditures relate to the total R&D expenditures by their Swedish MNE and trade partners.

Our results confirm that the Swedish R&D tax deduction raises employment related R&D expenditures in Swedish firms. Furthermore, our spillover result provides evidence that Danish firms linked to Swedish MNE partners that are affected by the tax deduction reduce their own R&D expenditures, while those Danish firms linked to Swedish trade partners affected by the deduction increase their R&D expenditures. In other words, within MNE networks R&D activity is substitutable, while it is complementary in trade networks. These results may reflect that when firms receive employment related R&D subsidies, they increase R&D activities and this spills over to trade linked partners, that also increase activities, perhaps due to increased demand in the trade network. The negative spillover effect in MNE linked firms, on the other hand, may reflect that MNEs reallocate tasks within the corporation such that R&D activities are shifted to the location with lowest marginal costs.

Our elasticity estimates provide evidence for magnitudes. The estimates combined with back-of-envelop computations predict that the Swedish tax reform led to the hiring of eight additional R&D workers in Swedish firms independent of the firms' MNE or trade

¹Kovak et al. (2021) focus on the effects of offshoring on MNE's employment outcomes.

relationships. However, in response to the same increase in R&D activity in Sweden, Danish MNE partners lay off four employees with college degrees, while Danish trade partners hire an additional 0.2 workers (though the latter is based on an elasticity estimate that is not significantly different from zero). Therefore, our results provide evidence that MNE and trade networks transmit common R&D shocks in one location quite differently to other locations. In particular, trade networks increase their overall R&D activity in response to tax incentives in one location, while MNE members are more likely to substitute R&D activities across locations.

Countries' significant investments to attract foreign companies with the hope of knowledge spillovers spurred a vast literature that focuses on two types of questions: (i) are MNEs more productive (exhibit greater TFP, paying higher wages, producing more output etc.) compared to non-MNEs in the same location and (ii) do potential productivity and wage effects transfer to domestically owned firms via domestic spillover effects? Recent papers provide evidence that MNEs tend to outperform domestic firms (Setzler and Tintelnot, 2021; Bircan, 2019; Jiang et al., 2018) while the evidence on domestic spillover effects historically has been a mix of negative effects (Girma et al., 2019; Lu et al., 2017; Haddad and A. Harrison, 1993; Aitken and A. E. Harrison, 1999; Djankov and Hoekman, 2000; Konings, 2001; Hu et al., 2005) and more recently positive effects (Eppinger and Ma, 2024; Gong, 2023; Malikov and Zhao, 2023; Setzler and Tintelnot, 2021; Bircan, 2019; Jiang et al., 2018; Keller and Yeaple, 2009; Haskel et al., 2007).² In the context of knowledge spillovers, these existing results can be understood to answer where knowledge embedded in MNEs ends up to affect productivity. Instead, we focus on where knowledge embedded in MNEs and trade networks is produced. Both are policy relevant. Policy makers care about if and where their initiatives affect R&D activity and productivity (Bilir and Morales, 2020).

Furthermore, existing evidence shows that labor turnover effects are important for MNE's to generate local spillover effects, i.e., former MNE employees bringing new ideas to local firms to improve productivity (Babina and Howell, 2024; Poole, 2013). Consistent with

²For excellent literature reviews also see Keller (2022), Görg and Strobl (2001), and Görg and Greenaway (2004).

this mechanism, our evidence focuses on a policy that reduces employment related R&D expenditures that affects firms hiring decisions instead of patent citations, capital investment, or alternative proxies for R&D activities. Based on this identification strategy, we find that employee related R&D activity is relatively footloose within MNEs. Consequently, local spillover effects based on employee turnover likely depend on where MNEs decide to engage in R&D activity. For example, Danish MNE affiliates are less likely to provide positive spillovers due to labor turnover in Denmark if their employee related R&D activity moves to Swedish MNE partners due to a subsidy. Our evidence also shows that this is less of a policy concern for international trade networks.

Two related papers directly examine MNE’s R&D activity. Bilir and Morales (2020) use structural estimation to provide evidence that R&D activity among U.S. parent firms and their affiliates is complementary. Knoll et al. (2021) use European MNE data to provide evidence that MNE’s patent citations follow local tax incentives but conclude that R&D activity is substitutable across locations.³ Conflicting results highlight the need for additional evidence, and we provide several contributions. First, we develop a plausibly exogenous identification strategy rooted in the details of a recent policy initiative. This mitigates concerns that current or future R&D policy may respond to existing domestic or foreign R&D activity. Second, we measure R&D activity consistent with the policy goal, i.e, to increase employment related R&D activities.⁴ Third, we jointly examine trade and investment related mechanisms.⁵ This is relevant from an identification point of view, because knowledge is embodied in trade flows and trade relationships may be correlated with MNE activities (Grossman and Helpman, 1990; Grossman and Helpman, 1991; Pavcnik, 2002; Amiti and Konings, 2007; Clerides et al., 1998; Van Biesebroeck, 2005; De Loecker, 2007; Keller, 2022). Furthermore, coherent evidence regarding trade, MNE, and R&D activities is policy relevant,

³For additional country and industry level evidence on R&D spillovers, see Coe and Helpman (1995), Keller (1998), Keller (2000), Keller (2002), Acharya and Keller (2009), and Keller (2022).

⁴The distinction between using innovation inputs and output is important, because firms introduce substantial innovations even if they do not engage in R&D and many patents protect relatively minor innovation Geroski et al. (1993).

⁵In general the literature tends to exclusively focus on MNE networks, FDI, or trade. However, recent research highlights the importance of jointly examining various globalization mechanisms in the context of patent related innovation activities (Aghion et al., 2024). A notable exception is Keller and Yeaple (2009).

because policy makers engage simultaneously with policy initiatives that address all of these objectives.

The rest of this paper proceeds as follows. Section 2 provides background on the Swedish R&D policy reform. Section 3 discusses data sources and data handling procedures. We discuss the empirical specifications and identification strategies in Section 4 before we discuss results in Section 5. Finally, Section 6 concludes.

2 R&D Policy Reform in Sweden

In January 2014 Sweden implemented an R&D-related tax reform that allows firms to deduct R&D-related employment expenses. The goal of the reform is to subsidize the cost of employees working in R&D to increase R&D activity and overall growth (*SOU 2012:66* n.d.). The policy was partly a reaction to similar earlier legislation in other countries, e.g. SkatteFUNN in Norway, that was examined by Bøler et al. (2015). This section provides background information related to the reform and discusses how the reform may affect firms' marginal R&D expenses.

The R&D tax deduction allows firms to deduct 10% of wages against the payable employee contributions. For example, for an employee with a monthly salary of 50.000 SEK, firms can reduce their monthly employer contributions by just under a third (from 15,710 to 10,710 SEK) and the benefit to the firm is immediate, i.e. in the month the firm claims the deduction. The deduction is designed to be simple to administer, and it is estimated that the administrative costs per person-year are only 1,000 SEK (*SOU 2012:66* n.d.).

Firms in all sectors and size categories are eligible for the R&D deduction. However, to qualify for the deduction, the employee must work 75% of their time with R&D and be between the ages of 26 and 65. Furthermore, the research must be systematic, and for commercial purposes to innovate new products or to substantially improve old products.

The tax reform stipulates a maximum deduction of 230,000 SEK per month or 2.76 million SEK per year. Consequently, if a firm has high employment related R&D expenditures

sufficient to qualify for the maximum deduction, then claiming the deduction does not affect the cost of hiring additional workers. On the other hand, if a firm has relatively low employment related R&D expenditures such that it does not initially qualify for the maximum deduction, then claiming the deduction reduces the cost of hiring additional R&D workers. Therefore, following Bøler et al. (2015), we expect that the R&D tax deduction reduces a firm's marginal cost of R&D related employment expenses only if the firm's existing employment related R&D expenditure is sufficiently low such that it does not qualify for the maximum deduction.⁶

Table 1 provides summary statistics highlighting the Swedish tax reform's potential to reduce firms' marginal employment expenses based on Swedish R&D survey data (see Section 3.1 for details). For context, column 1 reports the survey year, along with the number of reporting firms in column 2, and the share of firms reporting positive R&D expenditures in column 3. Then, column 4 reports the fraction of firms with sufficiently low R&D expenditures such that they would not qualify for the maximum deduction. Remember, a Swedish firm j does not qualify for the maximum deduction, if 10% of its employee related R&D expenditure in year t , $R\&D_{jt} \times 10\%$, falls below the deduction limit of 2.76 million SEK, i.e, if $R\&D_{jt} < 27.6$ million SEK. Of course, firms cannot take advantage of the deduction in the pre-reform periods 2011 and 2013. However, based on observed R&D expenditures in those years we can compute the fraction of firms with sufficiently low R&D expenditure such that they would not qualify for the maximum deduction, i.e., the fraction of firms with R&D expenditures that meet the restriction $R\&D_{jt} < 27.6$ million SEK. In the pre-reform period, we interpret this fraction as the share of firms for which we expect to see a reduction in marginal employment expenses due to the R&D tax reform based on their sufficiently low R&D expenditure in 2011 and 2013. For completeness, columns 5 and 6 report mean and median R&D expenditures.

Column 2 shows that the number of firms that report in the R&D survey is relatively stable across the survey years. Column 3 shows that a substantial number of firms don't

⁶Note that the deduction applies to firm groups.

report R&D activity. A potential reason for this is that R&D involves fixed costs such as equipment, space, and laboratories, as well as a fixed investment to develop the know-how to effectively engage in R&D and take new innovations to the market. Column 4 shows that based on observed R&D expenditure most firms do not anticipate to qualify for the maximum deduction. However, about 160 firms do qualify for the maximum deduction across the survey iterations.⁷ Columns 5 and 6 show that mean and median R&D expenditures are slightly decreasing over the sample period.

3 Data

This section describes our data sources and explains how we relate various samples to the Swedish R&D policy reform. All samples are available for the period 2011-2016. In addition, we summarize our procedures for identifying trade and MNE links between Danish and Swedish firms to examine spillover effects.

3.1 R&D Activity by Swedish Firms

We observe Swedish firms' R&D activity based on a biennial survey from 2011 to 2015 (Sv. Forskning och utveckling). The survey is collected in line with the Frascati manual and covers around 95% of the officially reported R&D expenditures in the Swedish business sector.⁸ The data includes firm identifiers that can be merged with other data sources.

The R&D survey includes: (i) all firms with at least 200 employees, (ii) all firms that have 10 or more employees within the sector Scientific research and development (SNI sector code 72), (iii) a sample of firms with 10-199 employees that are randomly selected conditional on size and sector. Firms that had over 5 million SEK in the previous R&D survey are always included in the survey. This sampling strategy leads to attrition among the smallest firms in the sample. Overall, the survey response rate is high (around 92% in both 2011 and 2013).

⁷For example, in 2011 it is about 2.3 percent of 6,951 firms.

⁸This can be seen from aggregating the expenditures on own R&D (variable v207) and comparing to the official aggregate data posted by Statistics Sweden, see series called Total intramural expenditure on R&D.

The survey collects data on both intra- and extramural R&D expenditures. For our purposes, we focus on the largest component of R&D expenditures: intramural labor costs of R&D personnel.⁹ Throughout, we simply refer to this component as "R&D expenditures".

As reported in Section 3.1, Table 1 provides summary statistics for each survey year 2011, 2013, and 2015. Each year contains data on about 7,000 firms of which between 13.3 and 18.0 % report some R&D expenditures and between 97.4 and 97.7 % report R&D expenditures below 27.6 million SEK (which triggers the maximum deduction amount). Among firms with some R&D activity, the average firm reported expenditures of between 38 and 44 million SEK, while the median firm spent between 3.8 and 5.0 million SEK.

In summary, the Swedish R&D survey provides useful information to examine the effect of the R&D reform on R&D activity, i.e., based on R&D expenditures in the pre-reform period we can examine if firms that are most likely to see a decrease in marginal employment costs due to the tax deduction will indeed increase R&D activities. However, it is not clear based on the employment expenditures in the R&D survey how the reform affects employment opportunities and how to examine if potential effects translate to Danish partner firms. To address these challenges we work with firm-level employment data which we will introduce in the next subsection.

3.2 Firm-Level Salaries of Workers with College Degrees in Sweden

We use Swedish register LISA which includes linked employer-employee data for the total population of Swedish firms including workers' education for the sample period, 2011-2016. We use this information to compute firms' total annual payments to workers with a college education. We label this variable as $\text{College-Salary}_{jt}$.

Our identification strategy requires that we observe which firms in the population that have experienced a decrease in the marginal cost of hiring additional R&D professionals. Therefore, we merge the population of Swedish firm-years with the $\text{R\&D}_{jt}$ variable con-

⁹According to the Frascati manual, these labor costs should include salaries, associated costs or fringe benefits, travel costs, payroll taxes and social security payments. This applies to both personnel that works full and part-time with R&D.

structured in the R&D survey data (see Section 2). The merge between the R&D survey and the college salaries is nearly perfect, as both data sources have the same unique firm identifiers. However, firms' inclusion in the R&D survey depends on the survey's sampling strategy. As a consequence, we can map firms' R&D expenditures from the R&D survey to the register data only for a subset of firms. In particular, for our estimation sample, we keep only those observations of firms for which we observe at least some information about R&D expenditures prior to the reform.

Table 2 provides summary statistics for college worker salaries for the population (excl. public administration) of firms with at least one college worker and the estimation sample, where we also observe the level of pre-reform R&D expenditures. The R&D survey targets firms that plausibly engage in R&D activity. Therefore, conditioning on observing R&D expenditure drops a large fraction of the firm population. However, as we would expect, the firms we drop are small. The resulting estimation sample consists of about 8,000 firms per year with an average total wage bill paid to workers with a college education of about 20 million SEK.¹⁰ In the average year, the sample constitutes more than 30 percent of college worker salaries in the population. Restricting attention to firms with at least one college worker maintains more than 99 percent of population-wide R&D expenditures.

Based on the effects of the R&D reform on college workers' salaries in Sweden, we examine spillover effects to Danish labor markets by examining Danish firms' expenses on college workers. To do so, we establish trade and MNE linkages between Swedish and Danish firms in the following two subsections.

3.3 Trade Links

We use data on firm-to-firm export flows within the EU collected by the tax authorities, Skatteverket in Sweden and Skat in Denmark, to determine if a Swedish-Danish firm pair trades with each other in any given year (2012-2016). Firms that trade with each other

¹⁰The yearly number of firms in the estimation sample (Table 2) exceeds the yearly number of firms in the R&D survey (Table 1). This is because we only require firms in the estimation sample to be present in the R&D survey in some pre-reform year, that is either 2011 or 2013 or both.

in the EU must declare the national firm identification number of their foreign trading partner as well as the value, and type of trade (trade in goods, services, or third-party trade). In practice, the exporter can sell a good or a service without VAT within the EU if they provide a valid VAT number of the foreign buyer on the invoice. The exporter then reports these sales to the local tax authorities (Skat/Skatteverket). Buyers (importers) are then responsible for calculating and paying the VAT in the destination country. By combining this data for both Denmark and Sweden we are able to construct cross-border firm-to-firm trade linkages between firms in Denmark and Sweden. The quality of these data is nearly complete due to the responsibility of the seller to provide a valid VAT number on the invoice. These VAT numbers can for example be validated through an EU VIES search service, which checks the validity of the firm identifier in the foreign country.

3.4 MNE Links

We observe if any given Swedish-Danish firm pair is a member of the same MNE network. If both firms in a given pair are members of the same multinational network, then we consider these firms linked by MNE activity.

We use two main datasets to construct these MNE linkages. First, the Bisnode Group Register (now part of Dun & Bradstreet) reports all domestic and international members of MNE groups that contain a Swedish firm. Second, Experian provides comparable information for Danish firms. We combine Bisnode and Experian to determine which Danish and Swedish firms are part of the same MNE firm group.

In particular, each MNE firm group network consists of one group mother and subsidiaries that are owned directly or indirectly by the group mother. The ownership structure is organized through chains of mother-daughter firm relations¹¹ For example, if firm A owns firm B, and firm B owns firm C, then we consider all three firms (A, B, C) members of the same MNE network. Note that we consider domestic and foreign MNE groups. For example, a foreign firm A may own Danish firm B and Swedish firm C. We then consider B and C

¹¹Each relation must be at least a 50% ownership stake.

members of the same MNE network independent of whether A is a Swedish firm, a Danish firm, or a firm located in some other country. Therefore, we take advantage of direct and indirect as well as domestic and international ownership structures to identify MNE groups and MNE membership of Danish and Swedish firms.

All Swedish firms in Bisnode and Danish firms Experian are identified by a domestic ID number that can be linked to Swedish and Danish register data. Foreign firms have either a name and a time-consistent ID (not an official local identification number). To enable us to merge these data, we perform a matching of Bisnode/Experian with local registers to add the local firm identifier. Overall, the match rate from the raw data is high both for the Bisnode and Experian data. For Bisnode, we are able to assign 99% of the Danish firms with an official Danish firm identifier (CVR number). Similarly, for Experian, we are able to match around 91% of the Swedish firms with an official Swedish firm identifier (organisationsnummer). In addition, we are able to identify firms that are linked via a third country. In our data, we are able to identify 1,584 firms in third countries that are linked to 2,129 Danish and 5,566 Swedish firms. Appendix A provides additional details regarding the matching process.

To examine the spillover effects of the Swedish R&D reform to Danish R&D activity, we use the trade and MNE links developed in the previous two subsections to Danish employer-employee data explained in the next subsection.

3.5 Firm-Level Salaries of Workers with College Degrees in Denmark

Next, we construct a sample to examine if the Swedish R&D reform spills across borders and affects Danish firms. We start with the register of Danish employer-employee-linked data (BFL) which we link to UDDA, a register containing information on the educational level of residents. For each Danish firm, i we then generate the total salaries paid to workers with college degrees: $\text{College-Salary}_{it}$.

Next, using the trade links and MNE links established in Sections 3.3 and 3.4, we determine which Danish firms were potentially affected by the Swedish R&D reform because

their Swedish trade and MNE partner were affected. We do this in three steps. First, we drop all Danish firms that, according to our trade and MNE links, do not have any trade or MNE partners in the sample of Swedish college salaries developed in Section 3.2 prior to the Swedish tax reform in 2014. Second, we merge the remaining sample of Danish firm-years with all of their trade and MNE partners' college salaries and their information of R&D expenditures, $R\&D_{jt}$. In the resulting sample, for each Danish firm i we now observe all of i 's trade partners, MNE partners, including their partners' expenditure on college salaries and employment related R&D expenditures based on the Swedish R&D survey, $R\&D_{jt}$.

Table 3 reports summary statistics for the population of Danish firms with college workers and the estimation samples of Danish firms with trade or MNE links. In the population (excl. public administration), the average firm pays just over four million DKK in salaries to its workers with college education. About every fourth firm is connected to a Swedish firm via trade or MNE. Conditional on an existing trade or MNE relationship, the average firm has just below six Swedish partners, whereas the median firm has two.

Our estimation sample contains around 12,000 firms each year, corresponding to 13.5% of the population. Firms in the estimation sample pay about five times more to workers with college education, i.e., Danish firms with trade and/or MNE partners in Sweden are relatively large.

As outlined above, estimation sample firms are required to have at least one Swedish counterpart prior to the reform in either 2012, or 2013, or both. Consequently, the share of Danish firms that have a Swedish MNE or trade partner in 2012 or 2013 is high and about 84 percent.

Conditional on having some relationships, the mean number of relationships is 3.4-4.0, while the median is 1-2. This is lower than for the population because we now only consider relationships that enter the Swedish estimation sample. Lastly, we have a particular interest in Danish firms with a Swedish MNE relationship prior to the reform. These constitute around 900-1,000 Danish firms each year, with a mean of around three Swedish MNE counterparts, while the median is one.

4 Identification

Our goal is to investigate if policy-driven R&D activity by Swedish firms affects R&D activity by their Danish trade and MNE partners. To accomplish this, we will first examine the effect of the R&D tax reform in Sweden on Swedish firms. Next, we study R&D spillovers from Swedish to Danish firms via trade and MNE linkages.

4.1 Swedish R&D Reform, R&D activity, and R&D Employment

Section 2 explains that the tax reform only has the potential to lower marginal costs of employment related R&D activity for those Swedish firms with sufficiently low employment related R&D expenditures, such that they do not qualify for the maximum deduction. Furthermore, we expect that the tax reform only affects those firms that actually take advantage of the R&D deduction. Unfortunately, the Swedish R&D survey does not report actual take up of the tax deduction. Instead, we follow an intention-to-treat type identification strategy proposed by Bøler et al. (2015).

This empirical strategy takes advantage of the fact that, we can identify the firms that potentially could be affected by the tax reform based on pre-reform employment related R&D expenses as measured in the R&D survey. To be precise, let $R\&D_{jt}$ be R&D activity measured as R&D related employment costs reported by Swedish firm j in year t in the R&D survey. Recall from Section 2 that the cost of additional employment related R&D expenditures is only affected by the R&D reform if $R\&D_{jt} < 27.61$ million SEK, i.e., if the firm does not qualify for the maximum deduction. We then consider a firm treated by the R&D reform if we expect that the firm will not qualify for the maximum deduction based on pre-reform R&D expenditures.

In particular, let $1\{t \geq 2014\} = 1$ denote an indicator variable for the year of the R&D reform and subsequent years. In addition, let $H_j = 1$ if firm j 's average annual R&D expenditure over the pre-reform period is below 27.6 million SEK and 0 otherwise. Combined, if $1\{t \geq 2014\} \times H_j = 1$ then we consider firm j treated by the R&D reform in

2014 and beyond.

We empirically examine if the R&D reform provided an incentive to increase R&D activity by relating employment related R&D expenditures to treatment according to the empirical model

$$\log \text{R\&D}_{jt} = \mu_j + \eta_t + \gamma 1\{t \geq 2014\}H_j + \varepsilon_{jt} \quad (1)$$

The coefficient of interest, γ , measures the response of R&D performance of those firms that are potentially affected by the R&D reform. We consider this an intention-to-treat effect.

The firm fixed effect, μ_j , and the time effect, η_t , account for firm and time-specific omitted variables. The identification assumption is that conditional on these fixed effects, firms' variation in R&D expenditure as captured by the error term ε_{jt} is not systematically related to potential treatment $1\{t \geq 2014\}H_j$, and that the R&D performance of firms potentially affected by the reform follows the same trend compared to those firms that are not affected prior to the reform. Without the fixed effects, the empirical model would likely not be identified. For example, the coefficient estimates for γ could then simply capture that smaller firms with less R&D expenditure are more likely to be affected by the reform. Furthermore, the time effects η_t capture overall trends.

To examine if the R&D reform affects firms that trade with Danish firms or firms that are linked by MNE ownership, we estimate equation (1) over the entire sample of the R&D survey as well as a sample that focuses only on firms that are linked to Danish firms by either trade or MNE links in the pre-reform period. To examine if MNE links in particular are affected, we augment equation (1) with an interaction term. Let $MNE_j = 1$ if Swedish firms j is linked to a Danish firm as explained in Section 3.4 and 0 otherwise. We then estimate

$$\log \text{R\&D}_{jt} = \mu_j + \eta_t + \gamma_1 1\{t \geq 2014\}H_j + \gamma_2 1\{t \geq 2014\}H_j MNE_j + \varepsilon_{jt} \quad (2)$$

In this specification, γ_1 captures differences in R&D performance between potentially treated firms and non-treated firms. The coefficient γ_2 allows for differences for firms that are linked

to Danish firms via MNE ownership.

We apply the same empirical model to examine the effects of the R&D reform on employment of college workers. Let $\text{College Salary}_{jt}$ be the salaries paid to workers with college education by firm j in year t . We then estimate the empirical model

$$\log \text{College Salary}_{jt} = \mu_j + \eta_t + \beta 1\{t \geq 2014\}H_j + \varepsilon_{jt}. \quad (3)$$

Although the empirical model remains similar to equation (1), the estimation sample will change, as we explained in Section 3.2. We observe college salaries in every year, and they are much less likely to be zero (with non-existing logs) compared to R&D expenditure. On the other hand, to apply our identification strategy, we still need to observe R&D expenditure in the Swedish R&D survey.

The coefficient of interest, β measures the response of employment of college workers of those firms that are potentially affected by the R&D reform. From an interpretation point of view, β captures R&D effects of the reform more broadly than γ . For example, firms that increase R&D activity in response to the reform, as captured by γ , may hire additional workers with college degrees to support R&D activities for example via improved management.

Finally, we allow for differences for those firms with MNE links in Denmark. Similar to equation (2) we introduce an interaction effect

$$\log \text{College Salary}_{jt} = \mu_j + \eta_t + \beta_1 1\{t \geq 2014\}H_j + \beta_2 1\{t \geq 2014\}H_j MNE_j + \varepsilon_{jt}. \quad (4)$$

The coefficient β_2 allows for different effectiveness of the R&D reform for Swedish firms that are linked to Danish firms via its MNE network membership.

4.2 Spillover Effects

Next, we develop an empirical strategy to examine if potential R&D effects in Sweden spill to connected Danish firms. We rely on the trade and MNE links we explained in Sections

3.3 and 3.4 combined with a reduced form and instrumental variable identification strategy similar to Kovak et al. (2021).

4.2.1 Treatment Approach

Our treatment approach extends the treatment indicator from the previous sections to Danish firms. In this identification approach, we compare Danish firms that are linked to Swedish firms (trade or MNE) that are potentially affected by the Swedish R&D reform according to the R&D survey information (i.e. $H_j = 1$) to Danish firms that are linked to Swedish firms (trade or MNE) and are not affected by the Swedish R&D reform (i.e. $H_j = 0$). We start by specifying the relevant treatment indicator and then explain the preferred empirical model.

Let Ω_i be the set of Swedish firms that Danish firm i is linked to within the pre-reform period by trade or MNE relationships. We consider a Danish firm i potentially affected by the Swedish R&D reform if its Swedish counterparts are affected by the reform. In particular, remember that $H_j = 1$ if a Swedish firm's R&D expenditure in the pre-reform period is sufficiently low such that its marginal costs of hiring additional R&D employees are potentially affected by the reform. We then let $D_i = 1$ if Danish firm i is linked to at least one firm in the Swedish R&D survey that is potentially affected by the Swedish R&D reform, i.e., $D_i = \max_{\Omega_j} H_j$, and zero otherwise. Finally, we combine the indicator D_i that identifies the potential treatment status of Danish firms with the pre/post-reform indicator to examine if potential R&D reform effects in Sweden translate to Danish R&D activity as measured by salaries paid by Danish firms to workers with a college education. That is, we estimate the empirical model:

$$\log \text{College Salary}_{it} = \mu_i + \eta_t + \delta 1\{t \geq 2014\} D_i + \varepsilon_{it} \quad (5)$$

The coefficient of interest δ reveals the R&D response of a Danish firm that is linked to a Swedish firm that saw a potential decrease in its marginal cost of R&D activity due to the

Swedish R&D reform relative to Danish firms that are linked to Swedish firms that did not experience the same potential marginal cost reduction.

If $\delta > 0$, then we conclude that R&D activity across linked firms is complementary. If $\delta < 0$, then we conclude that investment into R&D is a substitute across linked firms in Sweden and Denmark. The results section will focus on different samples to examine if R&D activities across trade and MNE partners are substitutes or complements.

4.2.2 Instrumental Variable Approach

The treatment approach in the previous section informs us about how the Swedish R&D reform directly affects Danish firms connected to Swedish firms, but it does not tell us how Danish R&D activity, proxied by salaries paid to college workers, responds to changes in R&D activity in connected Swedish firms. To examine this mechanism we adopt an instrumental variable approach similar to Kovak et al. (2021), that exploits the Swedish R&D reform.

Our specification of interest, the second stage, relates Danish firms' college salaries to the sum of college salaries across its trade and MNE partners according to the empirical model

$$\log \text{College Salary}_{it} = \alpha_i + \delta_t + \beta \log \sum_{j \in \Omega_i} \text{College Salary}_{jt} + \epsilon_{it}. \quad (6)$$

As defined above, Ω_i is the set of Swedish firms j that are linked to Danish firm i by a trade or MNE relationship. If the coefficient of interest $\beta > 0$, then Danish firms' R&D activity complements Swedish R&D activity. If the coefficient of interest $\beta < 0$, then Danish firms' R&D activity is a substitute for Swedish R&D activity.

The main identification challenge is simultaneity, i.e., if R&D activity across countries is a substitute or complement, then a shock to Danish R&D activity, ϵ_{it} will be systematically related to Swedish R&D activity across trade and MNE partners $\sum_{j \in \Omega_i} \text{College Salary}_{jt}$. We rely on Swedish firms' responses to the R&D reform to develop an instrumental variable and address this identification challenge.

The first step is to obtain predicted values for Swedish firms' college worker salaries based on their exposure to the R&D reform following the approach in equation (3). That is, we compute predicted values for Swedish firms' college worker salaries the following way:

$$\log \widehat{\text{College Salary}}_{jt} = \hat{\mu}_j + \hat{\eta}_t + \hat{\beta}1\{t \geq 2014\}H_j. \quad (7)$$

We construct our instrumental variable by adding predicted college salaries for all Swedish firms connected to Danish firm i , i.e., $\sum_{j \in \Omega_i} \log \widehat{\text{College Salary}}_{jt}$. We then estimate equation (6) with 2SLS using this instrumental variable. That is, the first stage equation is

$$\log \sum_{j \in \Omega_i} \text{College Salary}_{jt} = \alpha_i + \delta_t + \beta \sum_{j \in \Omega_i} \log \widehat{\text{College Salary}}_{jt} + \epsilon_{it}. \quad (8)$$

The standard identification assumptions are that the instrument predicts the endogenous variable and is excluded from equation (6). We will address the first assumption in the results section. The second assumption plausibly holds, because variation in the predicted values $\log \widehat{\text{College Salary}}_{jt}$ is due to the Swedish policy reform and the Swedish policy reform was not designed based on the R&D performance of Danish firms.

5 Results

This section reports and discusses the estimation results based on the data samples and identification strategies developed in Section 3 and 4. Across the various results, we emphasize estimation results for firms with trade and MNE links.

5.1 Effects of R&D reform on R&D Activity in Sweden

Using the information observed in the Swedish R&D survey (see Section 3.1), we estimate the OLS effect of the Swedish R&D reform on employment-based R&D activity according to the specification in equation (1). Table 4 reports the estimation results.

Table 4, column 1 reports the baseline estimation results over the observed Swedish R&D

Survey estimation sample. According to the estimate, we find that firms potentially affected by the R&D reform, i.e. $1\{t \geq 2014\}H_j = 1$, see a 11 percent increase in employment-related R&D expenses.

Column 2 focuses only on those firms in the estimation sample that have a trade and/or MNE link with a Danish firm. The estimated effect of the R&D reform increases to 12 percent but is similar to the estimate reported in column 1. This is not surprising. The observation counts in columns 1 and 2 show that imposing the restriction that firms need to have a trade and/or MNE link with Danish firms does not substantially affect the sample.

Column 3 introduces an interaction effect to the baseline empirical model to examine if Swedish firms with an MNE link in Denmark see different effects compared to those firms with a non-MNE trade link in Denmark according to equation (2). The estimates imply that we can not reject the hypothesis that the interaction effect is different from zero at conventional significant levels. Therefore, we do not find conclusive evidence that Swedish firms with trade links were affected differently than Swedish firms with MNE links by the R&D reform.

An advantage of using the R&D survey is that we observe self-reported R&D activity. A disadvantage is that we do not observe mechanisms by which the R&D reforms may have affected R&D activity. This makes it challenging to examine the transmission of R&D activity across trade and MNE networks. To address this challenge, the next subsection examines the effect of the R&D reform on salaries paid to workers with college education. We address this challenge in the next subsection.

5.2 Effects of R&D reform on College Salaries in Sweden

In this subsection, we examine if the Swedish R&D reforms affected employment for workers potentially engaged in R&D activity. Using the information observed in the Swedish register data (see Section 3.2), we estimate the OLS effect of the Swedish R&D reform on (log) college salaries according to equation (3). Table 5 reports the results.

The estimate in Table 5, column 1 shows that the R&D reform increased college salaries

in firms that were potentially treated by the R&D reform. We consider this evidence that the R&D reform affected firms' R&D activity through increased employment/payment to college-educated workers. To check if potentially treated firms were on a different trajectory already prior to the reform, we estimate a dynamic version of equation (3). Figure 1 presents the results and shows no evidence of differences in pre-trends. These results support the validity of our identification strategy.

Compared to the estimated effect of the R&D reform on R&D activity according to the Swedish survey data (see Table 4, column 1) the effect on college salaries is similar in magnitude but improves in precision. Overall, our takeaway is that college salaries paid by Swedish firms are a reasonable proxy for firms' broader R&D activity consistent with firms' self-reported R&D activity, and the larger sample of the Swedish register data compared to the R&D survey provides more conclusive evidence on the mechanisms and the overall effects of the R&D reform.

Table 5, column 2 focuses on only those Swedish firms that are part of a trade or MNE network with Danish firms. Although in this case, we see a substantial drop in the sample, the coefficient estimates and the standard errors remain the same.

Column 3 presents estimates to examine if firms that are engaged in MNE networks with Danish firms respond differently to the R&D reform than those firms engaged in a trade network with Danish firms according to equation (4). The estimates do not provide evidence that firms engaged in MNE networks respond differently to the R&D reform in terms of its effect on college salaries.

Based on the results presented in Table 4 and 5 we conclude that the Swedish R&D reform increased R&D activity in those firms that were potentially treated by the reform. Furthermore, based on college salaries and firms' self-reported R&D activity, the effect of the reform is similar for firm engaged in trade and MNE networks with Danish firms. Therefore, the results in the following sections will provide evidence for the transmission of a common and similar shock via trade and MNE linkages.

5.3 Reduced Form Spillover Effects

In this subsection, we examine if Danish firms that are linked to Swedish firms via trade or MNE networks are affected by their Swedish partners' R&D activity. In particular, we examine if among the Danish firms that are linked to Swedish firms, those firms whose partners were potentially affected by the R&D reform adjust their own R&D activity based on salaries paid to college workers in Denmark (see Section 3.5 for details) and equation (5). We estimate the model using OLS and Table 6 reports the estimation results.

The estimate in Table 6, column 1 provides evidence that R&D activity by Swedish firms affects their Danish partners' R&D activity. In particular, Danish firms with trade and/or MNE partners in Sweden who are potentially affected by the R&D reform increase their own R&D activity by about 13 percent. As in the previous subsection, we check if potentially treated Danish firms were on a different trajectory than other Danish firms already prior to the reform. We do so by estimating a dynamic version of equation (5) and plot the results in Figure 2. As above, there is no evidence of differences in pre-trends.

To examine if MNE and trade networks respond equally to foreign R&D shocks we focus on the sample of Danish firms with MNE links in Sweden (column 2) and Danish firms that are connected to Swedish firms by non-MNE trade links (column 3).¹² The estimate reported in column 2 provides evidence that within MNE networks R&D activity is a substitute, i.e., Danish firms that are linked to Swedish MNEs that are potentially treated by the Swedish R&D reform see a decrease in their own R&D activity. In contrast, the estimate in column 3 shows that within trade networks R&D activity is a complement, i.e., Danish firms that trade with Swedish firms that are potentially treated by the R&D reform see an increase in their own R&D activity.

Based on the reduced form approach, it is difficult to evaluate the extent to which Danish and Swedish members of the same trade or MNE networks substitute R&D activity. The next section presents instrumental variable estimates that clarify these relationships.

¹²Note that these two groups are not mutually exclusive since a Danish firm could have an MNE relationship with one Swedish firm and a non-MNE trade relationship with another.

5.4 IV Spillover Effects

This subsection reports elasticity estimates for Danish college worker salaries with respect to R&D-related employment in linked Swedish firms. We consider three types of estimates. First, as a benchmark, we estimate the relationship between Danish firms' salaries of college workers and the total sum of their Swedish partners' R&D activity according to equation (6) with OLS. Second, we re-estimate equation (6) applying the instrumental variable strategy discussed in Section 4.2.2. Finally, we will relate Danish college workers' salaries directly to the instrumental variable constructed in Section 4.2.2 in a reduced form exercise. Table 7 reports the results.

Panel A provides the OLS results. The coefficient estimates reported in columns 1, 2, and 3 all suggest that R&D activity within trade and MNE networks are complements, i.e., an increase in R&D activity as proxied by college workers salaries in Sweden results in an increase in college worker salaries in Denmark across all (column 1), MNE (column 2), and trade linkages (column 3).

Panel B reports instrumental variable estimates and the conclusions are markedly different.¹³ The estimate in Column 1 is positive but not significant. The positive sign suggests that estimated across all links, R&D activity within trade and MNE networks is complementary across network members.

Column 2 provides estimates that focus on the sample of MNE links. According to the estimate, a one percent increase in total R&D activity across all Swedish MNE partners leads to a 0.4 percent decrease in Danish firms' salaries paid to college workers. Therefore, within MNEs R&D activity is a substitute.

Column 3 focuses on trade links, and the coefficient estimate is positive but not significant. In summary, the results of Panel B, columns 1 to 3 are in line with the reduced-form evidence reported in Table 6. Pooling across trade and MNE links results in estimates that suggest that R&D activity is complementary across members of trade and MNE networks. However,

¹³For all the instrumental variable estimates, the instrument is predictive and not weak based on standard test statistics.

leveraging our data we are able to distinguish MNE from trade networks and the evidence shows that although R&D activity is a complement across members of a trade network, it is a substitute across firms that are part of an MNE network.

Panel C reports the results when we relate log college worker salaries directly to the instrumental variable. Reassuringly, the estimates follow a similar pattern as the instrumental variable estimates reported in Panel B.

We interpret the instrumental variable estimates in Panel B as the causal effect on a Danish firm's R&D activity from a change in the combined R&D activity by its Swedish counterparts (where R&D activity is proxied by salaries paid to college workers). To get a better sense of the magnitudes, we use the estimates to perform a rough calculation of the effect of the Swedish R&D reform on the number of college workers in Swedish and in the Danish MNE counterparts, respectively. First, recall from Table 2 that the reform increased R&D activity by about 10 % for firms below the deduction cap prior to the reform. Since Swedish firms with Danish MNE relationships paid 36 million SEK in college salaries, this amounts to an increase of about 3.6 million SEK, which, by applying the average yearly wage, corresponds to an increase of about eight college workers. How large is the effect on Danish MNE counterparts in comparison? Applying the estimated elasticity of -0.40, a 10% increase in R&D activity in a Swedish firm is accompanied by a 4% drop for the Danish MNE counterpart. Based on average values of salaries paid and annual wages for the Danish estimation sample, this 4% drop corresponds to almost four college workers. If we instead focus on Swedish and Danish firms connected through trade relationships, the reform incentivizes Swedish firms to hire about five additional college workers, which translates into an increase in college employment of about 0.2 for the average Danish counterpart (taking the estimated elasticity of 0.11 at face value even though it is not statistically different from zero).

6 Conclusions

In this articles we combine several data sources to examine the allocation of R&D activity within trade and MNE networks. We take advantage of a quasi-random policy experiment that incentivizes R&D activity in Swedish firms. Linking Swedish firms to Danish firms via trade and MNE networks, we then estimate substitution elasticities in R&D activity among MNE and trade network members. Our data and identification strategy provides evidence that while R&D activity is a strategic complement among trade networks members, it is a strategic substitute among MNE members.

These results may reflect that when firms receive employment related R&D subsidies, they increase R&D activities and this spills over to trade linked partners, that also increase activities, perhaps due to increased demand in the trade network. The negative spillover effect in MNE linked firms, on the other hand, may reflect that MNEs reallocate tasks within the corporation such that R&D activities are shifted to the location with lowest marginal costs.

Our results are policy relevant. Policy makers simultaneously engage in globalization activities via investment and trade promotion. If R&D activity and its associated knowledge is easily substituted across network members, then R&D incentives may affect the location of firms' research activities, but not their productivity. On the other hand, if engineers etc. engaged in R&D are responsible for local spillover effects due to labor turnover, the increased R&D activity due to subsidies may result in beneficial local spillover effects.

Whether R&D activity among trade and MNE members is complementary or substitutable is also important from a labor market point of view. Our results provide evidence that within trade networks, as R&D increase in one part of the network, total expenditures on employees most likely engaged in R&D (i.e. number of workers plus wages) increases in other parts of the network. Within MNE networks, an increase in R&D in one part of the network leads to a decrease in the demand and compensation for workers engaged with R&D in other parts of the network.

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7 Tables

Table 1: R&D labor expenditures in Sweden according to R&D survey

	(1)	(2)	(3)	(4)	(5)
	#Firms	Share of firms with R&D > 0 (%)	Share of firms with R&D < 27.6 M (%)	Mean R&D, conditional on R&D > 0 (M SEK)	Median R&D, conditional on R&D > 0 (M SEK)
2011	6,951	13.3	97.7	44	5.0
2013	7,232	14.6	97.6	41	4.4
2015	6,789	18.0	97.4	38	3.8

Notes: The table presents data from the Swedish biennial R&D survey for the years 2011, 2013, and 2015.

Table 2: Swedish firms with college employees, population and estimation sample

	Population			Estimation sample		
	#Firms	Mean college salaries (M SEK)	Total college salaries (B SEK)	#Firms	Mean college salaries (M SEK)	Coverage of total college salaries (%)
2010	141,966	3.5	493	8,598	18	31
2011	147,680	3.6	525	8,810	19	32
2012	152,554	3.6	553	8,790	20	32
2013	157,762	3.7	578	8,670	21	32
2014	163,309	3.7	608	8,358	23	31
2015	168,100	3.8	642	8,058	24	31
2016	172,422	4.0	682	7,813	26	30

Notes: "Population" is all Swedish firms (excl. public administration) with at least one employee with a college degree. "Estimation sample" is the subset of firms that appear in the biennial R&D survey prior to the reform (that is in 2011 and/or 2013).

Table 3: Danish firms with college employees, population and estimation samples

Population						Estimation sample, any relationship					Estimation sample, MNE relationships				
	#Firms	Mean college salaries (M DKK)	Share with some links (%)	Mean links cond. on some	Mean links cond. on some	#Firms	Mean college salaries (M DKK)	Share with some links (%)	Mean links cond. on some	Mean links cond. on some	#Firms	Mean college salaries (M DKK)	Share with some links (%)	Mean links cond. on some	Mean links cond. on some
2010	83,611	4.1	-	-	-	11,919	21	-	-	-	1,007	35	-	-	-
2011	84,786	4.1	-	-	-	12,530	20	-	-	-	1,036	36	-	-	-
2012	86,328	4.2	26	5.9	2	12,919	21	84	3.4	1	1,015	38	94	3.2	1
2013	87,994	4.3	26	5.8	2	12,842	21	84	3.4	1	1,004	40	93	3.1	1
2014	90,354	4.3	26	5.8	2	12,388	23	72	3.8	2	940	45	88	2.9	1
2015	94,133	4.3	26	5.8	2	12,028	24	69	3.9	2	910	49	84	2.8	1
2016	98,363	4.4	25	5.9	2	11,581	26	68	4.0	2	889	53	81	2.7	1

Notes: "Population" consists of all Danish firm-years with college employees. These are then merged with the population of Swedish firm-years with college employees (presented in Table 2). "Estimation sample" restricts Danish firms to the Danish estimation sample (as outlined in 3.5) and Swedish firms to the Swedish estimation sample (as outlined in 3.2 and presented in Table 2). "Estimation sample, MNE relationships" differs from "Estimation sample" by ignoring trade links and only considering MNE links.

Table 4: Effects of R&D Reform on labor R&D Expenditure

Outcome:	log R&D labor expenditures		
	(1)	(2)	(3)
$1\{t \geq 2014\}H_j$	0.11*	0.12*	0.17*
	(0.064)	(0.064)	(0.090)
$\dots \times MNE_j$			-0.10
			(0.13)
Firm sample	All	Any link	Any link
Firm FEs	YES	YES	YES
Year FEs	YES	YES	YES
Observations	2,203	2,050	2,050

Notes: Description of estimation samples. All: Firms are present in the biennial R&D survey prior to the reform (2011 and/or 2013), and firm-years report positive labor R&D expenditures according to the biennial R&D survey (2011, 2013, 2015). Any link: Firms have a trade and/or MNE relationship with at least one Danish firm prior to the R&D reform (2012-2013). Standard errors in brackets are clustered at the firm.

Table 5: Effects of R&D Reform on College Salaries

Outcome:	log College salaries		
	(1)	(2)	(3)
$1\{t \geq 2014\}H_j$	0.10** (0.041)	0.099** (0.043)	0.080* (0.047)
$\dots \times MNE_j$			0.018 (0.086)
Firm sample	All	Any link	Any link
Firm FEs	YES	YES	YES
Year FEs	YES	YES	YES
Observations	58,842	37,934	37,934

Notes: Description of estimation samples. All: Firms are present in the biennial R&D survey prior to the reform (2011 and/or 2013), and firm-years have at least one employee with a college degree (2011-2016). Any link: Firms have a trade and/or MNE relationship with at least one Danish firm prior to the R&D reform (2012-2013). Standard errors in brackets are clustered at the firm.

Table 6: Reduced Form Effects of R&D Reform on Danish Firms

Outcome:	log College salaries		
	(1)	(2)	(3)
$1\{t \geq 2014\}H_i$	0.13*** (0.042)	-0.23** (0.11)	0.15*** (0.045)
Firm sample	Any link	MNE	Trade only
Firm FEs	YES	YES	YES
Year FEs	YES	YES	YES
Observations	85,359	6,573	83,257

Notes: Description of estimation samples. Any link: Firms have a trade and/or MNE relationship with at least one Swedish firm prior to the R&D reform (2012-2013), and firm-years have at least one employee with a college degree (2011-2016). MNE: Firms have at least one Swedish MNE relationship prior to the R&D reform (2012-2013). Trade only: Firms have at least one Swedish trade relationship that is not also an MNE relationship prior to the R&D reform (2012-2013). Standard errors in brackets are clustered at the firm.

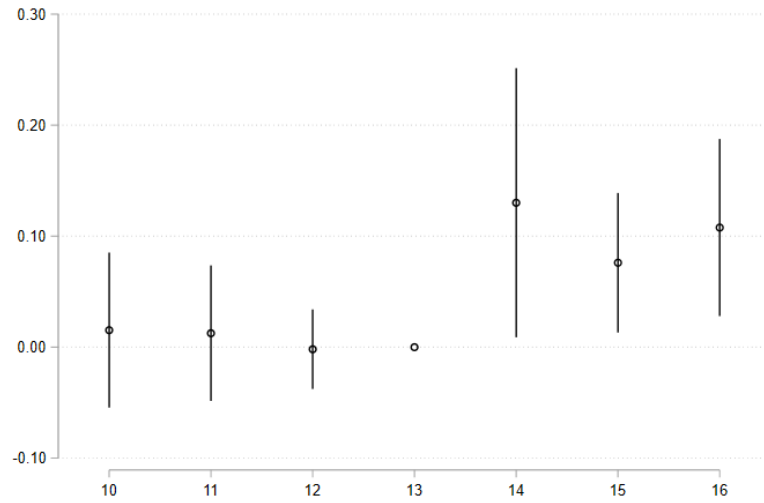
Table 7: IV Effects of Swedish R&D on Danish Firms

Outcome:	log College salaries		
	(1)	(2)	(3)
<i>Panel A: OLS</i>			
$\log \sum_{j \in \Omega_i} y_{jt}$	0.022** (0.011)	0.054* (0.031)	0.021* (0.011)
<i>Panel B: IV</i>			
$\log \sum_{j \in \Omega_i} y_{jt}$	0.062 (0.068)	-0.40*** (0.15)	0.11 (0.070)
<i>Panel C: Reduced form</i>			
$\sum_{j \in \Omega_i} \widehat{\log y_{jt}}$	0.00035 (0.00046)	-0.0033* (0.0018)	0.00064 (0.00046)
Firm sample	Any link	MNE	Trade only
First-stage F-stat	741	127	698
Observations	85,359	6,573	83,257

Notes: Estimation samples correspond to those in Table 6. Standard errors in brackets are clustered at the firm.

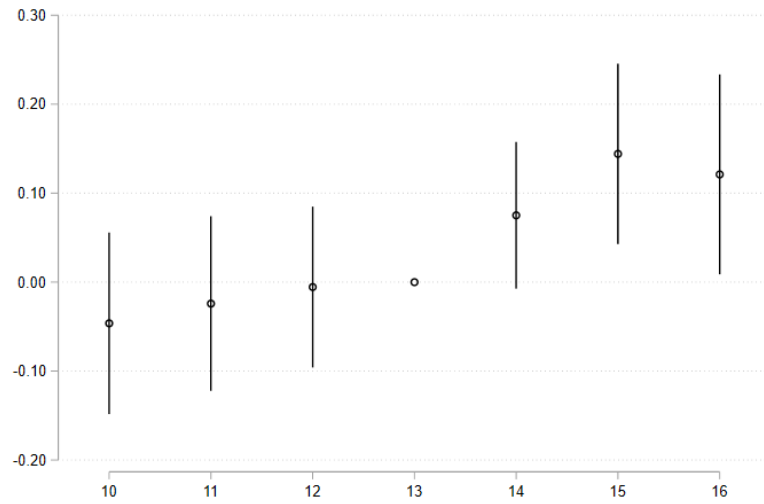
8 Figures

Figure 1: Effects of R&D Reform on College Salaries in Sweden



Notes: Estimation sample is similar to column 1 of Table 5, see table notes for details.

Figure 2: Effects of R&D Reform on College Salaries in Denmark



Notes: Estimation sample is similar to column 1 of Table 6, see table notes for details.

Appendices

A Construction of firm-to-firm ownership links

This appendix¹⁴ describes the construction of extensive firm-to-firm ownership linkages between firms in Sweden and Denmark. By merging a Swedish group register from Bisnode with a Danish firm ownership register from Experian, we construct a dataset containing all ownership linkages involving a Danish or Swedish firm along with information on the linkages’ underlying firm-groups.

Both the Bisnode and Experian datasets include information on the group structure. Both datasets include domestic firm identifiers but lack an official firm ID for foreign firms. To construct a firm-to-firm matched data that can be linked to other microdata, we must add official identifiers from other sources. This appendix describes how that match is conducted. The overall match rate is high, and we are able to find a Danish firm identifier for 98.8% of the Danish firms in the Swedish data and 91% of the Swedish firms in the Experian data.

A.1 Bisnode: The Swedish Group Register

The first dataset is the Swedish Group Register collected by the data analytics company Bisnode (now part of Dun and Bradstreet). Groups need to submit consolidated accounts (Swedish: Koncernredovisning) that encompasses the group mother and all the subsidiary daughter firms as if they were a single economic unit. In 1996, Bisnode started to manually collect this data and updated yearly since. This data is of high quality and used for example to form the population of international firms and foreign ownership by Statistics Sweden (SCB). The group register includes information on the global business group structure of all groups that include at least one Swedish firm. A “Group” is an ownership structure between legally distinct firms that are under common financial management. For a firm to be included in a group, it must be under majority control by the group mother (directly or indirectly through ownership chains).

¹⁴A more detailed description and the accompanying code are available on request.

In the Swedish Group Register, a “group” consists of one group mother, and then all subsidiary firms which are ultimately fully, or partly, owned by the group mother. The Group Register includes, among other variables, names and firm ID numbers (official Swedish “organisationsnummer”) of all firms located in Sweden. However, when a firm in the group is located outside of Sweden the same variables are included while the firm ID is in those cases a serial-number. Hence, for foreign (Danish) firms in the Group Register the firm ID does *not* consist of the official foreign firm ID (for Danish firms the ID is called a CVR number). To construct firm-to-firm ownership linkages between Denmark and Sweden, that can be linked with other firm level data, we need to add the official Danish firm ID number (CVR) to the Group Register. Below, we document how we add these identifiers to the data.

A.2 Structure of the data

The Bisnode Group Register describes the group structure of all groups where Swedish firms are involved, the period in which these firms are included in the group, the ownership percentage and which country the firm is from. Since, a firm needs to be majority controlled to be included in a group, a single firm can only be in one group at any point in time.¹⁵ The ownership structure is organized through chains of mother-daughter firm relations, in which the mother firm owns all or part of the daughter firm. There is only one group mother in any group, but there can be multiple subsidiary/intermediate mother firms. Hence, the group mother is not necessarily the direct mother to all firms in the group but rather the mother of the intermediate mother firm.

Each observation in the register includes a firm ID specific to the firm in question (official firm ID if a firm is Swedish and a serial number otherwise). Each observation is identified by the combination of the firm ID variable ‘od12’ and year. For each observation, firm-year,

¹⁵However, in the Group Register we do observe a small share of firms with multiple observations in the same year. This can stem from firms changing their accounting period in a year or the selling/buying of firms when the accounting periods do not perfectly overlap. Hence, if a firm has been sold after the accounting period ends of the group selling but before the end of the group buying, the same firm can have multiple observations in a year. Around 1.2% of the observations (1% of the firms) relate to firms with multiple observations within a year. Of those observations, roughly 40% are related to firms that are a part of multiple groups under the same year. The remaining cases are related to firms with multiple accounting periods in a year.

we can also see the firm ID of the mother firm that directly owns the firm (variable om12) as well as the firm group ID (variable ok12) of the ultimate group mother. From these three firm ID variables, we can imply the relation between any two firms in a group through a chain of mother-daughter relations. When a firm is Swedish, an official firm identifier is used and a serial number for foreign firms.

A.3 The Matching Process

The goal is to connect all Danish firms in the Group Register with their corresponding CVR-number. We do this by matching the names in the Group register with those found in the public Central Business Register (CVR - Det Centrale Virksomhedsregister). As there may be discrepancies in the naming, this section describes the matching process. Over 90% of this problem is solved with minimal editing and generalizations of the names before merging (for example by translations, removing of punctuation marks etc.), but a smaller number of matches are found with other methods (manual matching or utilizing fuzzy name matching).

A.4 Reformatting of data (Prepare_datasets.ipynb)

This section describes the process executed in the python scripts (saved as Jupyter Notebooks) Prepare_datasets.ipynb and matching.ipynb. To simplify the matching, the Bisnode and CVR-number datasets are reformatted to be more alike. This includes e.g.: 1) all letters are made to lowercase, 2) reformatting of language specific letters in the names are replaced with a common interpretation e.g. {ø:oe, æ:ae, å:aa, ö:oe, ä:ae, á:a, é:e, è:e, à:a, á:a}. 3) identifying and specifying different types of Danish firms (e.g. A/S, ApS). We reformat the CVR data to the same format as the Bisnode data (e.g. transform to yearly data).

A.5 Steps of the matching process (matching.ipynb)

The matching process is done in steps. At each step, the names of the firms are generalized a bit and then a merged. The merge is done using the merge_match()-function defined in the

notebook. The matches are saved, while the unmatched names in the Group Register are moved to the next step. After all the steps of name generalizations and direct merging, fuzzy name matching is done. At the end, a few remaining names are matched manually using <https://data.virk.dk/>. There are 9,613 unique od12-numbers in the raw data (some of them have multiple names), and we find a corresponding CVR for 9,533 of them. These numbers include minority owned firms and branches, which are excluded for the analysis of this paper.

Step 1 - Merge on exact name and type: First we merge on ‘name’ and firm type. This removes all the ‘exact matches’ where there are no discrepancies in the names. The `merge_match()`-function also only matches firms, if the CVR has been active in at least a subset of the active period in the Group Register. This step matches 74.8% of the Group Register names.

Step 2 - Removal of e.g. punctuation marks: In the second step, punctuation marks are removed, & is translated to the Danish word “og”, and “oe” and “aa” are generalized to “o” and “a”. Some examples of other changes include: international:int, and:og, av:af, of:af, limited:ltd, denmark:dk, danmark:dk, holdings:holding and sweden:se. Spaces are also removed in this step. This step matches 9.5% of the Group Register names.

Step 3 - Ignoring firm type: Match only on name and not on firm type. This step matches 2.9% of the Group Register names.

Step 4 With spacing, removal of recurrent words and common translations: Same as above but use spacing but remove recurrent words with little unique firm (e.g. ‘asset’, ‘assets’, ‘broderne’, ‘brdr’, ‘brodrerne’ ‘holding’). Some words are given a common translation. This step matches 3.5% of the Group Register names, meaning that 90.7% of the Group Register names have been matched at this point.

Step 5 - Fuzzy name matching. In the script the python package `fuzzywuzzy`¹⁶ is used,

¹⁶<https://github.com/seatgeek/fuzzywuzzy>

but the process could also be implemented in other languages. The package uses the Levenshtein distance¹⁷, which is a mathematical formula for calculating how different two strings are, to calculate a ratio of similarity from 0 to 100, for each remaining unmatched name in the Group Register data compared with all names in the CVR data (again first the names, then the binames). For each Group Register name, the highest ratio is chosen as the correct match, as long as it is above a certain threshold. The names which are compared are formatted in the same way as in the second step, but without removing spaces. This step matches 6.2% of the Group Register names.

Step 6 - Manual match <https://data.virk.dk/> and searching the internet. At this step 1.9% of the Group Register names are matched, while the remaining 1.2% are discarded.

Step 7 - Post-matching data checks: We perform a number of smaller checks on the data. See the online appendix for details.

A.6 Summary of Matching Process

The Group Register covers groups with a Swedish firm during the period 1995-2018. Even though our main aim is to investigate groups with a Danish connection, the register itself includes a much broader scope of foreign firms regardless of country of origin. Using the approach described above, **a match rate of 98.8% is achieved**. Of the matches, 74.8% was matched with minimal editing (only initial reformatting), while 15.9% are matched after some editing in steps 2-4. Hence, over 90% of are matched with minimal editing and are hence expected to be of high quality. The outcome is a list of the CVR-numbers of almost all Danish firms which are part of groups that includes a Swedish firm from 1995-2018.

¹⁷https://en.wikipedia.org/wiki/Levenshtein_distance

B Experian: Danish firm ownership data

Our goal is to create a dataset that includes all groups with a Danish or Swedish firm involved and where every Danish or Swedish ownership link is included. The Swedish Group Register includes comprehensive information on all groups where a Swedish company is involved. However, foreign companies (e.g. Danish) are generally only included in the data if they have a direct ownership-link to a Swedish firm. Hence, if a Danish group has multiple Danish firm and one of them is connected to Sweden, we may overlook such indirect ownership ties. For this, we need more information on links involving Danish companies. In appendix B we describe how we use data from Experian to solve this issue. The data from Experian includes the ownership structure of Danish groups from 1995 and forward.

The sections below describes how the Experian dataset is processed and made similar to Bisnode (add local firm identifiers). The work done in the python scripts (saved as Jupyter Notebooks) `Experian_clean_and_match.ipynb`, `Od12_key.ipynb`, `Third_country_key.ipynb`, `Experian_long.ipynb` and `Experian_final.ipynb`.

B.1 Cleaning dataset (`Experian_clean_and_match`)

The Experian data is in a wide format, where one observation fully characterizes an ownership link. We have ‘RelationStart’ and ‘RelationSlut’ variables that indicate when the linkages started and ended, along with the ownership percentage. Furthermore, we have the name and country code for both companies involved, along with the CVR numbers for Danish companies. For Danish companies, we have another unique ID called ”KOB”. Prior to matching to Bisnode the data is cleaned and we remove observations where we have missing CVR numbers, names, missing both start and end dates. We remove missing values and add CVR numbers using step 1 and 2 above for a small number of observations (less than 2%).

B.2 Creating an ID key for Swedish companies in Experian (`Od12_key.ipynb`)

To fully cover all Danish-Swedish links, and to make sure we create a structural consistent dataset, we want to not only merge the datasets on Danish companies but also on Swedish

companies when possible. Therefore, we have created a key that connects the Swedish companies in Experian with their organizations number from Bisnode.¹⁸

To do this, we have started with giving all Swedish companies in Experian a serial number. These serial numbers are given so that companies with the same name have the same serial number.¹⁹ We then match the companies with Bisnode using three steps:

1. We try to match the companies by both name matching and by matching the Danish companies, they are linked to. Every Swedish company in Experian is linked to a Danish company, which we can utilize to ensure a correct match. We use the name matching procedure described in section A.5 but adds the constraint that a match also has to be linked to the same Danish company (same CVR number) in both datasets.
2. We match the remaining companies using only the connected Danish companies. For this step, we divide the Swedish companies into two categories, mothers and daughters. For mothers: If a specific Danish company in a given time frame has a Swedish mother company with an ownership share above 50% in both datasets, we take the organization number from the Swedish mother in Bisnode and assign it to the Swedish mother in Experian ²⁰. For daughters: If a Danish company owns only one Swedish company in both datasets around the same time period, we match the two daughter companies. If a Danish company owns multiple Swedish companies in a specific time period, we only match if the time periods are identical in both datasets.
3. The last remaining are companies where we have not been able to find the equivalent Danish link in Bisnode. For them, we match on names using the first two steps from the name matching procedure of section A.5. We also use a time restriction, saying that the time periods where the firms are in each dataset has to overlap with at least

¹⁸Note that we do not have a comparable data source to public CVR register available to us. We hence rely on the firms in the Bisnode data to add Swedish local firm identifiers.

¹⁹Unfortunately, Experian sometimes have different observations involving the same company but where the company name is spelled slightly different. To get around this we have used a reformatting function that uncapitalized all letters, removes different signs and removes spacing.

²⁰Note that all majority links have an ownership share above 50%, so only one mother is possible for each daughter

one year.

In total, we have managed to match 74% of the Swedish companies in Experian with an organization number from Bisnode. Around 53% of the Swedish firms in Experian have been matched through the first step, 10% have been matched through the second step and 11% have been matched through the third step. Note that we remove minority owned firms for our analysis which tend to have lower match rates. The match rate for the sample of majority owned firms is considerably higher, around 91%. ²¹

C Restructuring Experian to the Bisnode Structure (Experian_long.ipynb)

In order to make the merge of the datasets easier, we want to restructure the Experian dataset so that it follows the Bisnode structure. To do this we firstly need to convert Experian into a long format where each ownership linkage has an observation in every year where it is active. We have the 'RelationStart' and 'RelationSlut' variables that indicate when the linkages started and ended. However, some observations have an empty 'RelationStart' variable, which by Experian's own explanation means that the relation is older than 2000. But as most of these linkages also end before 2000 ('RelationSlut' is before 2000) we have set the missing 'RelationStart' values to 1994 (the year the Bisnode data also starts). Out of a total of 570,000 useful observations in Experian, there are 20,000 of them that are missing Relation Start values. Linkages that ended earlier than 1994 are removed from the data. We then change Experian into a long format by creating an observation in every year between their 'RelationStart' and 'RelationSlut' years for a given ownership linkage. Secondly, we need to add information about the group for which the ownership linkage is connected to. Bisnode has a group mother variable that identifies the group, and a layer variable that states which layer of the group a given linkage lies in.²²

²¹The matches from the first and third step are very secure. For the third, we have been very conservative by only choosing to use the first two steps of the name-matching process in order to minimize wrong matches. In cases of disagreement, we rely on the Bisnode data.

²²The data includes minority ownership links, which we also refer to as interest links. These links offer the possibility that firms have multiple owners and thereby can be part of multiple groups. The problem now arises if these firms also are the owners of other firms. It now becomes non-obvious how to decide what groups these firms should be part of. We therefore decide not to add group information to any minority

For the majority ownership links, we add group information by first identifying all mother companies in Experian that do not also have an observation as a daughter, i.e. they are not owned by another company in the data. These companies are thereby the data's group mothers. We then add the group-mother and layer variables to the data by iterating through linkages, starting with the group mothers and then marking all companies in the same ownership chain with the same group mother, and defining layer as the iteration number.

D Third country key (Third_country_key.ipynb)

Using Experian and Bisnode, it is not only possible for us to identify direct ownership linkages between Danish and Swedish companies. We also have the potential to identify companies that are linked through a common third country mother company. In these instances, we will have an ownership linkage with the Danish daughter in Experian and an ownership linkage with the Swedish daughter in Bisnode. To identify these linkages when merging the datasets, we need to make sure that the third country mother has the same (fake ID in both Experian and Bisnode. This is what the third country key is for. We use the following approach to create the key:

1. Pull out all foreign mother companies in Experian and create fake IDs starting with 9999.
2. Pull out all foreign mother companies in Bisnode. Here we already have fake IDs
3. Match these companies on name and country code using step 1,2 and 4 from the matching process of chapter A.5
4. Save the fake IDs from Experian and Bisnode along with the first and last year where the company is in both datasets.

In total, we have managed to find 1,584 foreign companies, that in are linked to 2,129 Danish companies and 5,566 Swedish companies. They have an average lifespan of 5.39 years when they are in both datasets.

ownership links, which means that the group structures in our data are unique.

E Descriptive statistics on cleaned datasets

Above we described how we constructed a firm-to-firm ownership dataset of all Danish and Swedish firms by merging and linking various datasets. In the first part, we used data from the Swedish data provider Bisnode on the group structure of Swedish firms. In the second part, we used data from the Danish provider Experian on the group structure of Danish firms. Below, we present some descriptive statistics on the cleaned datasets.

The final Bisnode data includes around over 450 thousand firms (unique ‘od12’), 146 thousand (unique Group mothers, ‘ok12’) and over 3.3 million observations. Table 8 shows some yearly descriptive statistics on the entire Group Register from Bisnode. From the table we can see that in 2018 alone we have 2903 firms and 1104 groups that are Danish.

The final Experian dataset is created by combining the long format dataset with the Swedish ID key and the third country key, which adds the ID numbers found in Bisnode. Table 9 shows descriptive statistics on the final Experian dataset. After cleaning and reformatting the data, the final Experian data includes around over 290 thousand firms, 116 thousand unique group mothers and over 2.8 million observations. Table 9 shows some yearly descriptive statistics on the entire Group Register from Experian. From the table we can see that in 2018 alone we have 2764 firms and 1533 groups that are Swedish.²³

²³See file `Experian_final.ipynb`.

Table 8: Bisnode: The number of firms/groups (regardless of partner country). All numbers are counts.

	Firms	SE firms	For. firms	Groups	SE Groups	For. groups	DK Firms	DK groups
1995	73345	64381	8964	19733	18145	1588	918	316
1996	85771	74769	11002	24095	22214	1881	1135	427
1997	86701	73668	13033	23944	21901	2043	1280	457
1998	90408	75376	15032	24414	22191	2223	1431	501
1999	93809	77320	16489	25119	22726	2393	1551	550
2000	101380	83272	18108	27298	24483	2815	1798	654
2001	105649	87053	18596	28891	25941	2950	1917	738
2002	109423	89691	19732	30173	26992	3181	2042	794
2003	112516	91735	20781	31179	27977	3202	2165	831
2004	115133	93955	21178	32195	28843	3352	2283	878
2005	122124	99814	22310	34585	31122	3463	2376	953
2006	130535	107231	23304	37172	33414	3758	2516	1025
2007	135779	111023	24756	37934	33907	4027	2633	1095
2008	140165	114521	25644	38870	34704	4166	2713	1158
2009	142778	116880	25898	39802	35454	4348	2661	1153
2010	149106	122794	26312	41762	37405	4357	2637	1124
2011	159208	132262	26946	45054	40554	4500	2708	1164
2012	166965	139575	27390	47348	42673	4675	2762	1168
2013	173841	145886	27955	49291	44531	4760	2791	1166
2014	183090	154360	28730	51649	46748	4901	2842	1175
2015	194252	164674	29578	54463	49403	5060	2903	1186
2016	202047	172444	29603	56131	51232	4899	2872	1138
2017	208705	178620	30085	57274	52354	4920	2864	1108
2018	213277	182061	31216	57485	52471	5014	2903	1114

Table 9: Experian: The number of firms/groups (regardless of partner country). All numbers are counts.

	Firms	DK firms	For. firms	Groups	DK Groups	For. groups	SE Firms	SE groups
1995	20190	16091	4099	7460	6168	1292	642	345
1996	23848	18986	4862	8652	7170	1482	762	398
1997	29303	23474	5829	10617	8894	1723	912	468
1998	35893	28848	7045	13089	10918	2171	1100	555
1999	42907	34836	8071	15824	13354	2470	1283	643
2000	49463	40588	8875	18548	15777	2771	1444	724
2001	56707	46196	10511	21301	18099	3202	1654	789
2002	59038	48535	10503	22328	19281	3047	1662	769
2003	65452	53806	11646	25062	21599	3463	1811	809
2004	72209	59339	12870	27813	24020	3793	1936	828
2005	76055	63300	12755	29583	25867	3716	1887	805
2006	83908	70452	13456	32930	28913	4017	1969	810
2007	93960	79697	14263	36978	32766	4212	2049	824
2008	103285	88130	15155	40727	36365	4362	2103	835
2009	111009	94870	16139	43785	39048	4737	2163	859
2010	117204	100296	16908	46352	41253	5099	2248	893
2011	122573	104456	18117	48369	43002	5367	2344	917
2012	125465	106870	18595	49284	43800	5484	2379	954
2013	129331	109723	19608	50823	44906	5917	2488	1032
2014	135317	114904	20413	53250	47160	6090	2577	1111
2015	144848	123558	21290	57267	50650	6617	2670	1229
2016	153930	133282	20648	61407	54732	6675	2658	1352
2017	163840	143177	20663	64837	58483	6354	2693	1423
2018	172911	152093	20818	68219	61766	6453	2764	1533