Economic Studies 212

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Trade, Innovation, and Gender

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ECONOMICS AT UPPSALA UNIVERSITY

The Department of Economics at Uppsala University has a long history. The first chair in Economics in the Nordic countries was instituted at Uppsala University in 1741.

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Abstract

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Essay I (with Olga Lark): We examine whether exposure to gender inequality at export destinations affects the gender wage gap in exporting firms. We motivate the analysis through a stylized model where wages depend on worker productivity, and men have a comparative advantage when trading with gender-unequal countries due to customer discrimination. Empirically, we use high-quality matched employer-employee data from Sweden and calculate how exposed firms are to country-level gender inequality through their export destinations. Although increased export intensity on average leads to a wider within-firm gender wage gap, the effect is entirely driven by trade with gender-unequal countries.

Essay II (with Daniel Halvarsson, Olga Lark, and Patrik Tingvall): We study how the associated need for communication with foreign partners when exporting shapes the gender wage gap. Specifically, we examine how the demand for interpersonal skills in trade and gender-specific differences in negotiations are related to the remuneration of men and women. Our key finding is that export of goods that are intensive in interpersonal contacts widens the gender wage gap. The negative wage effect is most pronounced for domestic exporting firms, which mainly deal with external contractors. We ascribe this result to a male comparative advantage in bargaining - a skill that is especially needed and rewarded when serving foreign markets, where intense contracting problems manifest themselves.

Essay III I study how firm-specific trade opportunities affect firms' R&D investments and innovative activities. To construct trade opportunities that are exogenous to firm-level decisions, I use the variation in export (import) patterns and exploit the fact that firms differ in their product-country exporting (sourcing) patterns. Both export and import opportunities generate firm-level growth, but the effects on innovation activities are very different for the two trade shocks. Export opportunities yield more R&D investments and innovations. On the other hand, import opportunities show no effects on R&D investments, and a negative impact on innovation.

Essay IV (with Patrik Tingvall): This paper explores regional variation in the effects of publicly sponsored R&D grants on SME performance. The results suggest there is no guarantee that the grants will impact firm growth, either positively or negatively. Positive growth effects are most likely to be found for publicly sponsored R&D grants targeting SMEs located in regions abundant with skilled labor, whereas the opposite is found for SMEs located in regions with a limited supply of skilled labor.

Keywords: International Trade, Gender Wage Gap, Export, Import, R&D, Innovation

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To Emma, Estrid, and Valde

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Uppsala, June 2023
Josefin Videnord

Contents

Introduction

International trade is an enormous economic force reshaping our globalized world. It connects industries, firms, and people across borders, and makes goods and services available in distant locations. While we have gained a lot of knowledge about the effects of international trade on macroeconomic conditions, we still know way too little about how it influences our society at the firm and individual levels. In this thesis, I address two important and understudied aspects in relation to international trade; gender inequality and firm-level investments in R&D and innovations.

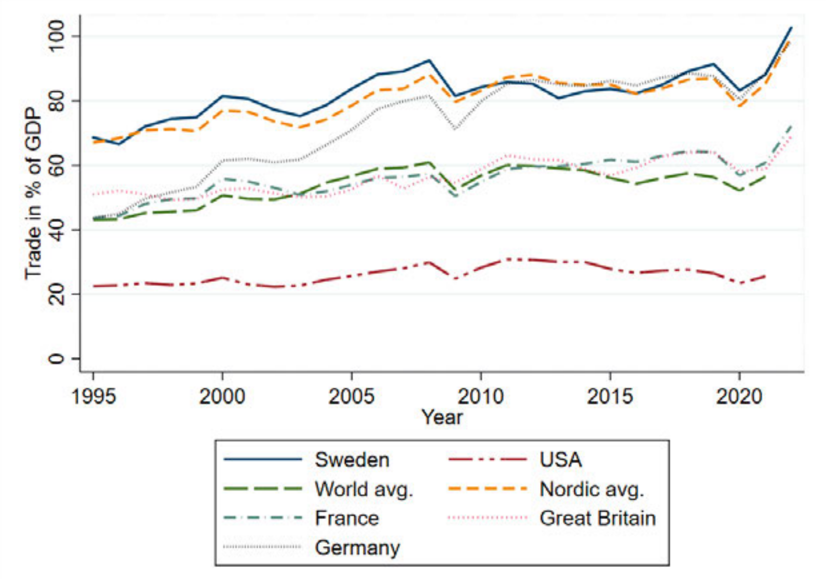

Figure 1. Trade in percent of GDP (World Bank data)

All of my chapters are empirical, using data from Sweden. Apart from being a country where researchers can access very useful and detailed data on my key research topics, Sweden is also an interesting case because of its high reliance on international trade. According to the World Bank trade data (illustrated in Figure 1), Sweden's total trade value corresponded to 103 percent of its GDP in 2022. The country is dependent on both exports and imports, but since the mid-80s, the export value has constantly been larger than the import value, generating a positive trade balance. The three most important goods exported in 2022 were vehicles for roads, mineral oils, and medical and pharmaceutical products.[1] Figure 1 shows trade in percentage of GDP for Sweden and some of its main trade partners, as well as the Nordic and world averages. As illustrated in Figure 1, the high Swedish trade dependency is similar to that of some European countries, like the other Nordic countries and Germany, but stands out in comparison to the world average and many other rich countries, including the United States, Great Britain, and France. The fact that numerous Swedish firms engage in international trade exposes a large part of the Swedish workforce to international markets and thereby the cultural, business, and gender norms among the trade partners. Whether this influences male and female labor market outcomes differently is the first topic of my thesis.

Gender

My focus on the intersection of international trade and gender inequality is motivated by the fact that there are good reasons to believe that trade and trade policies, often unintentionally when it comes to policies, are likely to have dissimilar impacts on men and women. Not only do men and women tend to work in different sectors and occupations, but they also tend to consume different goods and services (The World Bank, 2020). Therefore, depending on exactly which sectors or goods are affected by changes in trade patterns or policies, men and women will be hit differently in their varying roles as workers, consumers, or business owners (Korinek et al., 2021). These observations shed light on the importance of a continued focus on gender research in relation to international trade. While most of the existing policy discussion has been on developing countries, it is reasonable to assume that international trade also impacts labor market outcomes and economic equality between men and women in developed countries. Two of my essays, where I analyze how involvement in international trade influences the gender wage gap within Swedish firms, build on this notion.

Sweden is in many ways an appealing country for an analysis of international trade and gender inequality. At the same time as it is highly dependent on trade, it is also known for being a relatively gender-equal country with, e.g., generous parental leave benefits and a universal daycare system. The UN Gender Inequality Index (GII) constantly ranks Sweden as one of the most gender-equal countries in the world.[2] Despite this, there is clear evidence of gender differences in the labor market. As in other countries, researchers have documented that glass-ceiling effects and motherhood penalties contribute to the gender wage gap in Sweden (Albrecht et al., 2018; Angelov et al., 2016; Nekby, 2003). Furthermore, the over a decade-long trend of a

[1] https://www.scb.se/hitta-statistik/sverige-i-siffror/samhallets-ekonomi/sveriges-export (Accessed June 23, 2023)

[2] https://hdr.undp.org/data-center/gender-inequality-index (downloaded June 29, 2023)

gradually shrinking gender wage gap has turned into a growing gender wage gap in the aftermath of the COVID-19 pandemic. One possible explanation behind the changing trend is that workers in the female-intense service sector were hit the hardest by restrictions and failing demand. The average gender wage gap in Sweden today is 9.9 percent – implying women only earn 90.1 percent of men's wages. A large part of the wage differential is explained by men and women working in different occupations and sectors of the economy. However, even after controlling for occupation, age, education, and hours worked, the wage gap remains at 4.7 percent (Ekberg and Beijront, 2022). This residual unexplained difference may be due to gender discrimination, or other unaccounted factors. In this thesis, I discuss two such factors related to the non-gender-neutral impact of international trade.

In contrast to much of the earlier literature on gender gaps at the country or sector level, my thesis follows the recent strand of literature that explores gender differences within and across firms.[3] This approach requires access to register data where individuals can be followed over time, and where they are connected to the firms they work at. In my case, I further relate these data to information about international trade at the firm level. Methodologically, the two gender-related papers rely on insights from the small but growing empirical literature on firm-level exports and the gender wage gap, where Bøler et al. (2018) constitute a seminal contribution. The empirical strategies build on a "matched fixed-effects approach", where I compare the wage trajectories of men and women, within worker-firm matches, as firm-level trade patterns evolve. In contrast to Bøler et al. (2018), who investigate what happens to the gender wage differential when firms start to export, the focus here is on export intensity – the intensive margin of exports. Two main questions are addressed: i) does the *gender equality of trade-partner countries* matter for the within-firm gender wage gap? and ii) does the *contract intensity of the exported products* influence the gender wage gap? Thereby, my thesis contributes with new answers to questions related to if *who* you trade with, and *what* you trade, matters for the gender wage gap.

Below follows non-technical summaries of the two gender-trade papers:

Do Exporters Import Gender Inequality?
Co-authored with Olga Lark

The first essay examines whether exposure to gender inequality at export destinations affects the gender wage gap in exporting firms. The analysis is motivated through a stylized model where wages depend on worker productivity, and men have a comparative advantage when trading with gender-unequal countries. When interacting with customers who are primarily used to doing

[3] See, e.g., Card et al. (2016).

business with male counterparts, female workers may have restricted opportunities to generate revenues for their firms. This would occur also in firms operating in an otherwise gender-equal environment and reward workers in proportion to their performance. The potential unequal treatment of female workers would thus stem from the trade partner side rather than the employer side, in the style of Becker ([1957] 1971) customer discrimination.

To empirically investigate whether export linkages cause female wage penalties in firms selling to gender-unequal markets, we use Swedish matched employer-employee data and calculate how exposed firms are to country-level gender inequality through their export destinations. On average, increased exports have a negative effect on female relative wages, disregarding the destination dimension. The negative effect is, however, entirely driven by firms exporting to customers in gender-unequal countries. Increased exports to countries that are about as gender-equal as Sweden have no impact on the within-firm gender wage gap. The estimated magnitudes are of clear economic importance: if a Swedish firm shifts all of its sales from the most gender-equal destination (Denmark) to one of the most gender-unequal destinations (Saudi Arabia), female relative wages will fall by approximately 14 percent.

We find that female managers experience the most pronounced negative relative wage effects. Female managers, who are most likely to interact with foreign customers, appear to be particularly exposed to the gender inequality of export partners. The result for managers aligns with the insights from our stylized model, where the female workers most involved in trade with gender-unequal partners will face the most considerable wage penalties due to customer discrimination.

Bargaining for Trade: When Exporting Becomes Detrimental to Female Wages

Co-authored with Daniel Halvarsson, Olga Lark, and Patrik Tingvall

The second essay studies how the associated need for communication with foreign partners when exporting shapes the gender wage gap. The question we ask is how the demand for interpersonal skills in trade and gender-specific differences in negotiations are related to the remuneration of women and men. Women are often argued to be more skillful when it comes to interpersonal contacts, while men are known to perform better in bargaining situations. To measure the need for interpersonal contact and/or bargaining skills when trading we use the well-established Nunn (2007) contract intensity index.

Our key finding is that export of goods that are intensive in interpersonal contacts widens the gender wage gap. The negative wage effect is robust across various specifications and is most pronounced for domestic exporting firms, which mainly deal with external contractors. We ascribe this result to a male comparative advantage in bargaining—a skill that is especially needed and rewarded when serving foreign markets, where intense contracting problems manifest themselves. To further underline the connection between exports and demand for negotiation skills, we show that the observed negative effect is primarily driven by white-collar workers, and in particular, by managers and sales workers. Based on our findings, we conclude that doing business with a variety of partners across the globe alters the job skill demands of exporters.

Innovation

The second focus of my thesis is on the link between international trade and technological innovations - two fundamental drivers of a changing global economy. Although both trade and innovations are likely to have big impacts on aggregate welfare and inequality, we still know little about their interaction. Just as with gender inequality and trade, Sweden stands out as a country with high levels of innovative activities and is currently ranked as the third most innovative country in the world (World Intellectual Property Organization, 2022). Sweden's high trade dependency combined with the high innovation rate makes it an ideal setting to study the innovation-trade link.

My analysis of the trade impact on innovation connects to an active and recent literature that uses changes in export or import opportunities within firms as a way to estimate how trade affects firms, see e.g. Hummels et al. (2014) and Aghion et al. (2022). The strategy exploits the fact that trade patterns are "sticky" so firms that sell products to (or buy from) certain countries tend to continue to do so for extended periods of time. As a consequence, their overall exports and imports will fluctuate when demand or supply changes in these destination (or source) countries. The identification strategy is often referred to as a shift-shares strategy, inspired by Bartik (1991). After being heavily debated and questioned by economists, shift-share instruments have gained popularity again.[4]

The final paper of my thesis is the only chapter that does not relate directly to international trade. Instead, it focuses on publicly sponsored R&D grants. The question of what the role of governments is, if any, in supporting firms' R&D activities has spurred a divided literature, with strong voices both for and against publicly sponsored R&D grants.[5] The fact remains that most countries and governments actively support firm innovation as a part of their industrial policy; pointing to the relevance of investigating the effects of these grants. If we take a step back from the issue of publicly sponsored R&D grants being or not being, other questions emerge. The fourth and final paper of my thesis addresses the question of how regional access to skilled labor matters for the

[4] See summaries of the shift-share literature in, e.g., Goldsmith-Pinkham et al. (2020) and Borusyak et al. (2021)

[5] Sandström et al. (2019) provide a thorough summary and discussion of the literature on publicly sponsored R&D grants and governments involvement in innovation policy.

success of R&D grants. Firms in Sweden are located in regions with different potentials and resources for innovation. Many rural regions have a low concentration of skilled labor - an input argued to be essential for R&D to take place. On the other hand, there are a few city hubs where the relative supply of highly-educated workers is large. The paper investigates if the effects of publicly sponsored R&D grants are different in regions with a higher concentration of skilled labor. From a policy perspective, it connects to two important questions: i) should governments hand out publicly sponsored R&D subsidies to firms? and ii) could the effect of such subsidies be influenced by factors outside of the firm (e.g. regional access to skilled labor)?

Below follows non-technical summaries of the two R&D papers:

The R&D and Innovation Effects of Firm-Specific Trade Opportunities

The third essay explores how firm-specific trade opportunities affect R&D investments and innovative activities. I use the variation in export and import patterns and exploit the fact that firms differ in their product-country exporting (sourcing) patterns to construct trade opportunities that are exogenous to firm-level decisions. One contribution of the paper is to build trade-opportunity variables that reflect the trade partners' comparative demand or supply changes. The relevance of the trade-opportunity variables is tested by estimating the impact of export (import) opportunities on trade volumes and prices within a set of granular product-country-firm fixed effects models. The results show clear impacts of trade opportunities on trade volumes. Moreover, prices are increasing when export opportunities are improving, but there is no statistically significant effect on prices from improved import opportunities.

My main results show that both export and import opportunities generate firm-level growth in sales, value-added, overall employees, and high-skilled employees. Moreover, the employment effects are not limited to low-skilled production workers; the impact on high-skilled employees (including Ph.D:s) is proportional to the overall employment effect. Despite having similar positive effects on firm growth, the effects on innovation activities are very different for the two trade shocks. Export opportunities (i.e., an increase in the potential market size) lead to more R&D investments (spending, employees, and intensity) and more product and process innovations. On the other hand, import opportunities show no effects on R&D investments, and the impact on product, process, and service innovation is negative. The findings for import opportunities are in line with the suggestion that imported intermediates are complements to some R&D activities but potential substitutes to in-house innovation.

Regional differences in effects of publicly sponsored R&D grants on SME performance
Co-authored with Patrik Tingvall

The fourth essay investigates the regional variation in the effects of publicly sponsored R&D grants on the performance of small and medium-sized enterprises (SMEs). The local supply of skilled labor is argued to be a critical factor for the growth chances of innovative and R&D-intensive firms. Therefore, we ask the question if there are any regional differences in the growth effects of publicly sponsored innovation and growth targeting grants, and what role human capital may play. From a policy and efficiency perspective, the regional dimension may be critical to understanding an intervention's outcome. A few earlier studies have taken a regional perspective on how publicly sponsored subsidies impact firm performance (Bannò et al., 2013; Herrera and Nieto, 2008; Piekkola, 2007; Doloreux, 2004). Overall, the results from these studies suggest that regional characteristics matter for the impact of R&D subsidies, but the source of the heterogeneity remains unknown, calling for further studies. Our contribution is to explicitly focus on the role of the local supply of human capital in shaping the impact of R&D grants. This approach is motivated by the close link between innovation and human capital. Our main results suggest there is no guarantee that the grants will impact firm growth, either positively or negatively, although SMEs located in regions abundant with skilled labor are more likely to experience positive growth effects.

Contributions

Taken together, the contributions of my thesis are, first and foremost, providing a broader scene for research in international trade and the parts of our society it influences. Important aspects, such as gender equality, have long been overlooked in the international trade literature. In economic and trade theory, women and men are still assumed to benefit equally from globalization and trade reforms. Recent evidence, however, suggests differently and points to vastly different implications for women and men from trade and trade reforms. If we learn in which ways globalization and international trade may cause gender divergence or convergence, we can actively work toward a more gender-equal world. Furthermore, trade policies could be designed to mitigate gender differences, and firms involved in international trade could consciously work on generating equal opportunities for all of their workers. Contributing with some pieces of the puzzle of how and why international trade can cause increasing gender wage gaps in developed countries is thus a contribution to the fields of international trade and gender economics.

The second contribution of my thesis is connecting technology and trade by investigating the influence of trade on technological innovation. Today we know that both technology and trade are changing the world, but much of the research in economics views the two as forces disconnected from one another. I contribute with a paper highlighting the connection and interdependence between these two drivers of growth. Finally, my thesis contributes to the literature investigating the effects of publicly sponsored R&D grants, which is still a highly policy-relevant question. Industrial policy is once again a hot topic for governments, and questions about public involvement in developing, and regulating, new technology may never have been a more pressing issue than it is today.

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Essay I. Do Exporters Import Gender Inequality? *Co-authored with Olga Lark*

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1 Introduction

Despite a steady decline in recent decades, the gender wage gap remains resilient with significant variations across countries. Globalization, at the same time, increasingly exposes workers in exporting firms to markets with varying levels of gender equality. Although earlier studies have analyzed the connection between gender equality and globalization from several angles, the estimates and explanations regarding the impact of exports on the gender wage gap are still inconclusive, calling further attention to the mechanisms underlying this relationship (Bøler et al., 2018; Bonfiglioli and De Pace, 2021; Halvarsson et al., 2022). We contribute to the literature by proposing that the impact of increased exports on the within-firm gender wage gap depends on the gender equality of the destination country.

Our study is motivated by the notion that firms' participation in international trade increases the number of direct interactions between domestic workers and foreign buyers.[1] Female workers may have restricted opportunities to generate revenues for their firms when interacting with customers who are primarily used to doing business with male counterparts. Hence, gender-biased customer discrimination, in the style of Becker ([1957] 1971), may create a comparative advantage for male workers in the exposed firms, leading to an elevated gender wage gap therein. Such effects could also arise in firms that operate in an otherwise gender-equal environment and remunerate workers in proportion to their performance. That is, the potential unequal treatment of female workers would stem from the trade partner side rather than the employer side. In this paper, we formalize the above idea in a stylized model and empirically investigate whether export linkages cause female wage penalties in firms selling to gender-unequal markets.

In the empirical analysis, we use matched employer–employee data from Sweden from 1997 to 2015. Sweden offers an interesting setting to study the nexus between gender inequality and trade since it is one of the most gender-equal countries, besides being a small, trade-dependent economy with an export value of around 50 percent of its GDP.[2] We also have access to wage data for a substantial part of the Swedish private sector workforce, which enables us to look at actual wages instead of income. As a broad metric of gender inequality in the destination countries, we use the well-established Gender Inequality Index (GII) developed by the United Nations.[3] We generate firm–year specific destination weights based on the share of the firm's annual sales directed to each destination, including nationally within Sweden. We then calculate firms' export-weighted exposure to gender inequality by multiplying the

[1]See the literature on the importance of business travels and in-person meetings, e.g., A. B. Bernard et al. (2019), Battiston et al. (2020), Söderlund (2020), and Startz (2021).

[2]The World Economic Forum, Global Gender Gap Report, 2022; The World Bank, 2022 [https://wits.worldbank.org/CountryProfile/en/SWE]

[3]As a sensitivity check, we also use the Gender Gap Index (GGI) from the World Economic Forum, as well as the subindices of the GII.

country weights with each destination's gender inequality index. Finally, we estimate the gender-specific wage impact of the obtained weighted exposure score.

To identify the effect of interest, we estimate a wage regression with fixed effects for each employer–employee match and for each firm–year observation. By doing so, we exploit within-firm variation in wages and export patterns while holding selection on the worker, firm, and match level constant. Additionally, the main empirical model is extended by including even more granular fixed effects. First, we add firm–year–occupation fixed effects, and later, firm–worker–occupation fixed effects.[4] These occupation-specific fixed effects further control for variation in wages from shocks to particular occupations within the firm and from workers switching occupations while employed at the firm.

Our main finding is that exports to gender-unequal destinations increase the within-firm gender wage gap. Disregarding the destination dimension, we find that increased exports negatively affect female relative wages on average. We show, however, that this negative effect is entirely driven by firms exporting to customers in gender-unequal countries. Increased exports to other countries, which are about as gender-equal as Sweden, have no impact on the gender wage gap. The estimated magnitudes are of clear economic importance: if a firm shifts all of its sales from the most gender-equal destination (Denmark) to one of the most gender-unequal destinations (Saudi Arabia), female relative wages will fall by approximately 14 percent. Notably, the gender wage gap at mean wages in our sample is 10 percent, which further underlines the nontrivial magnitude of the observed effects.

We find the most pronounced negative wage impacts for female managers, who appear to be particularly exposed to the gender inequality of export partners. The result for managers aligns with the insights from our stylized model, where the female workers most involved in trade with gender-unequal partners will face the most considerable wage penalties due to customer discrimination. Although we also find adverse effects for other female white-collar workers, these are only about a third as large as the estimated effects on female managers' wages. For blue-collar workers, we do not detect any significant change in the gender wage differential when exports to gender-unequal destinations surge.

The main result is robust to various sample cuts and specification tests. It is proven to hold when removing small firms, non-manufacturing firms, and workers with short tenure from the sample. In addition to being robust to different sample restrictions, the estimated effect stays intact when including controls for firm-level profitability and imports, and when controlling for

[4] Since switching an occupation might be an outcome of its own, restricting workers to stay in the same occupation might potentially introduce bias to our estimates. Hence, the models with additional occupational fixed effects serve as auxiliary rather than main specifications.

the overall income levels of trade partners. Additionally, we also account for several mechanisms discussed in the previous literature on exporting and the gender wage gap and show that the effect of destination gender inequality on female relative wages stays intact.

Earlier studies have analyzed the effects of trade liberalization and tariff cuts on gender-specific labor market outcomes, see e.g., Juhn et al. (2014) and Sauré and Zoabi (2014). Our findings add to the study of globalization and gender and, foremost, to the literature on exports and the remuneration of men and women. Specifically, we contribute by examining how the gender inequality of trade partners might translate to the gender wage gap in exporting firms. Using matched employer–employee data from Norway, Bøler et al. (2018) show that college-educated females experience a wage penalty relative to their male colleagues in exporting firms. They attribute the finding to lower temporal flexibility and commitment among women, which are important for firms operating across different time zones. We establish that accounting for such time-zone effects does not affect our results.

A related strand of the literature has emphasized the role of gender-specific skills in understanding the interaction between exports and the gender wage gap. Bonfiglioli and De Pace (2021) point to female comparative advantages in social skills as an explanation for their finding that exports reduce the gender wage gap for German white-collar workers while increasing the gap for blue-collar workers. Relatedly, Halvarsson et al. (2022) find, using the same Swedish data as in our paper, that export of goods that require tight buyer–seller interaction (higher degree of contract intensity) widens the within-firm gender wage gap. We reaffirm that the contract intensity of traded goods is relevant for the wage gap, but accounting for this channel does not influence our main findings.

We also connect to the literature studying how foreign ownership—another important aspect of globalization—allows for transferring of cultural and gender norms across international borders and thereby leads to non-neutral effects on gender-specific labor market outcomes (Kodama et al., 2018; Tang and Zhang, 2021; Halvarsson et al., 2022). The overall message of this literature is that foreign investors transplant their corporate culture and gender norms to foreign affiliates, affecting wages and labor market participation of women in the host countries.[5] In contrast to the foreign ownership literature, we focus

[5] In a broader sense, our paper also connects to the literature on gender inequality in the labor market (Altonji and Blank, 1999; Blau and Kahn, 2000; Goldin, 2014), the literature on differences in psychological attributes and bargaining power across genders (Olivetti and Petrongolo, 2016; Card et al., 2016; Blau and Kahn, 2017), the literature on globalization and wages (Helpman et al., 2010; Akerman et al., 2013; Autor et al., 2013; Helpman et al., 2017), as well as to the literature on exporting and wages (A. Bernard and Jensen, 1995; A. B. Bernard and Bradford Jensen, 1999; Schank et al., 2007; Munch and Skaksen, 2008; Irarrazabal et al., 2013; Krishna et al., 2014; Macis and Schivardi, 2016; Barth et al., 2016; Bødker et al., 2018; Frías et al., 2022).

on the role of firm export activity in shaping its gender wage gap. To clean our estimates from the potential effects of foreign ownership, we exclude foreign-owned firms from the main analysis and consider only domestically owned exporters.[6]

Overall, the empirical evidence on internationalization and gender inequality has been diverging with findings of positive, negative, or no effects of exporting on the gender wage gap. We contribute to the literature by documenting that increased exports to gender-biased destinations widen the within-firm gender wage gap among exporters when destination and source countries differ in their equality levels. We show that international trade may generate negative externalities across countries by transferring gender inequality and affecting workers in the most gender-equal countries. Together with previous findings of the opposite effects in an unequal low-income country setting[7], the evidence suggests that the processes of globalization and gender equality convergence are deeply intertwined. This paper elicits the idea that, in an increasingly globalized world, a universal shift in attitudes toward higher gender equality is crucial to achieving the full potential of gender parity in society and the labor market.

The rest of the paper proceeds as follows. Section 2 presents a stylized theoretical framework that illustrates how gender inequality at export destinations may enter a worker's wage through customer discrimination. Next, in section 2.2, we connect the theoretical framework to the empirical strategy and demonstrate the wage equations we estimate. The data is described in section 2, while our results and robustness checks are presented in section 3. Finally, section 4 concludes.

2 Theoretical Framework

This section outlines a stylized theoretical framework that captures the idea that the gender wage gap in exporting firms may depend on gender equality in destination countries. Notably, the effects we model may arise even if an exporting firm is profit-maximizing and pays its workers in proportion to their productivity. The proposed partial equilibrium model helps us to visualize the mechanism we have in mind of how gender inequality at export destinations may spill over to the wage of an individual worker. The model also motivates the functional form and the sets of control variables (fixed effects) used in the empirical analysis.

We propose an augmented version of a standard bargaining wage-setting framework (see, e.g., Card et al. (2016)) where the worker's wage at a given firm is equal to a weighted average of the revenue productivity (the inside

[6]The foreign-owned firms are included in the sample as a robustness check and are proven not to influence any of the main findings significantly.

[7]See, e.g., Khoban (2021).

value of the employer–employee match), and the market value (the outside option). The log wage (w_{ijt}) of individual i at firm j at time t can therefore be expressed as follows:

$$w_{ijt} = \Omega_i + \theta\left(r_{ijt} - \Omega_i\right) \tag{1}$$

where Ω_i is the worker i's outside option, θ is worker bargaining power (between 0 and 1), and r_{ijt} is revenue productivity from a given employer–employee match at time t. Productivity is match-specific, and all surplus is shared in a predetermined manner between the worker and the firm, as in, e.g., Fredriksson et al. (2018) and Jäger et al. (2020).

To introduce differences in productivity across genders, we assume that female workers produce less revenue than their male colleagues when exporting to gender-unequal destinations due to customer discrimination in the style of Becker ([1957] 1971). Thus, the revenue productivity (r^d_{ijt}) by worker i for firm j in destination d and year t can be written as:

$$r^d_{ijt} = a_{ij} + b^d_{jt} + \psi \times Female_i \times GII^d_t \tag{2}$$

where a_{ij} is worker match-specific productivity, b^d_{jt} is firm efficiency in destination d, $Female_i$ is a dummy variable for being a female, GII^d_t is the gender inequality in destination d, and finally, ψ is the weight on customer discrimination, similar to the customer discrimination coefficient in Becker ([1957] 1971)). We model the gender-specific impact of customer discrimination (ψ) as constant. Still, it is natural to assume that its relevance will differ depending on worker involvement in communication with the export partner. We will explore how the customer discrimination coefficient varies across occupations in the empirical analysis.

From the destination-specific revenue productivity expression, the log wage (rent sharing) of individual i working at a firm j at time t can be rewritten as:

$$w_{ijt} = \Omega_i + \theta\left(\sum_{d=1}^{N} \omega^d_{jt} r^d_{ijt} - \Omega_i\right) \tag{3}$$

where ω^d_{jt} is the share of sales to destination d. The destination-specific revenue productivity, r^d_{ijt}, is weighted by ω^d_{jt} and summed across all destinations, $d = 1,..,N$. Equation (3) can now be expressed as the following empirical wage equation:

$$w_{ijt} = \mu_{ij} + \eta_{jt} + \beta \times Female_i \times \sum_{d=1}^{N}\left(\omega^d_{jt} \times GII^d_t\right) \tag{4}$$

where μ_{ij} equals to $(1-\theta)\Omega_i + \theta a_{ij}$ and collects the employer–employee match-specific terms. The firm–year-specific terms are, in turn, collected in $\eta_{jt} = \theta \sum_{d=1}^{N} \omega^d_{jt} b^d_{jt}$. In the regression model outlined in section 2.2, both μ_{ij}

and η_{jt} are estimated by employer–employee match and firm–year fixed effects, respectively. The estimated coefficient β captures the gender-specific wage impact of customer discrimination in the destination countries. It arises as a combination of θ, the bargaining power, and ψ, the effect of customer discrimination at the export destination. Our framework does not allow separating the two effects, but since θ is between 0 and 1, a negative β should necessarily imply a negative ψ. Moreover, we assume θ to be similar across genders, and thus θ will only impose a scaling effect on β.[8]

The model allows for the possibility that firms with higher productivity in a particular market self-select into that market. To rule out that all firms would perfectly sort themselves into the most profitable destination, we implicitly assume matching frictions on the product–destination market as in the international trade model by Eaton et al. (2022).[9] Any firm-specific productivity effect will also be captured by the firm-year (η_{jt}) fixed effects.

In a similar vein, the model allows for assortative matching of workers across firms. It implies that workers with certain characteristics (gender, ability, or skills) are more likely to be employed by firms operating in a particular market. As before, the identifying variation is guaranteed by implicitly assuming frictions that prevent workers from perfectly sorting across firms when they change their customer mix. Imperfect labor adjustments due to search and matching frictions are standard in the literature, see in particular Black (1995) and Rosén (2003) on the models with search frictions, where discrimination in some firms but not others generates adverse wage effects rather than perfect segregation of workers. In addition, the impact of worker–firm match-specific attributes is captured by the μ_{ij} fixed effects included in the model.

The proposed stylized model imposes a structure on the relationship between wages, foreign sales, destination-specific firm revenues, and customer discrimination. The model also serves as a basis for the empirical specification described in detail in the next section. Importantly, the inclusion of both employer–employee match (μ_{ij}) and firm–year (η_{jt}) fixed effects in the empirical specification allows us to address the potential endogeneity and selection concerns when estimating the effects of interest.

3 Empirical Framework

3.1 The Measure of Export Exposure to Gender Inequality

To estimate the effect of increased exports to gender-unequal countries on female relative wages (the coefficient β in equation (4)), we need a firm-specific

[8]In the empirical framework, we control for the possibility that men and women have different bargaining power by adding an interaction term, Female$\times$ln(Sales), reflecting if rents, in general, are shared differently across genders.

[9]Eaton et al. (2022) document that product market frictions are as important as "iceberg" trade costs in hampering trade flows.

and time-varying proxy for gender inequality at export destinations. We construct such measure, the export-weighted gender inequality index of firm j at time t, as follows:

$$GII_{jt} = \sum_{d=1}^{N-1} [\omega_{jt}^{d} \times GII_{t}^{d}] \tag{5}$$

where we weigh the destination-specific gender inequality index, GII_t^d, by the firm j export share to destination d and then sum over all destinations, $d = 1,..,(N-1)$. The weights are denoted by ω_{jt}^d and constructed as the ratio of exports to a destination d in year t over the total export value of the firm j in the same year. Formally,

$$\omega_{jt}^{d} = \frac{Export_{jt}^{d}}{TotalExport_{jt}} \tag{6}$$

In equation (4) of the stylized model, domestic sales are implicitly included in the destination-specific gender inequality index while summing across all destinations $d = 1,..,N$. Specifically, the domestic market is treated as one of the firm's destinations. On the other hand, the empirical gender inequality index from above, GII_{jt} (equation (5)), does not account for domestic sales. To correct for that, we obtain a measure of Gender-Inequality-Weighted Sales (GIWS) in the next step as follows:

$$GIWS_{jt} = GII_{jt} \times EI_{jt} + GII_{t}^{SWE} \times (1 - EI_{jt}) \tag{7}$$

where firm export intensity, EI, is defined as the total export value over total sales in a particular year. The $GIWS_{jt}$ measure represents a sum of the two terms: the export-value weighted gender inequality index, GII_{jt}, interacted with the firm export intensity EI_{jt}, and a domestic gender inequality index, i.e., the gender inequality index for Sweden GII_t^{SWE}, interacted with the share of domestic sales, $(1 - EI_{jt})$. Conceptually, the $GIWS$ reflects the firm overall exposure to gender inequality and discrimination through its sales, be it domestic or foreign, and constitutes an essential building block of the empirical analysis.[10] A higher value of $GIWS$ implies a larger share of the total firm sales going to gender-unequal destinations, whereas we capture sales to all markets, including the Swedish domestic market.

3.2 Empirical Model

The empirical model builds on the empirical wage equation (4) extended with the $GIWS$ measure from equation (7). Using the full set of matched employer–employee data, we estimate the following model:

[10] In what follows, we omit subscript jt on the $GIWS_{jt}$ and GII_{jt} for brevity.

$$
\begin{aligned}
ln(wage)_{ijt} =& \beta[Female_i \times GIWS_{jt}] \\
&+ \mu_{ij} + \eta_{jt} \\
&+ \mathbf{X}'_{it}\gamma + \mathbf{F}'_{jt}\phi \\
&+ \varepsilon_{ijt}
\end{aligned} \tag{8}
$$

where β is the main coefficient of interest which shows the effect of the *GIWS* on female relative wages. As emphasized in section 2, the key elements of our identification strategy are the employer–employee match fixed effects, denoted by μ_{ij}, and firm–year fixed effects, denoted by η_{jt}. The employer–employee match fixed effects care for workers' sorting into firms. Otherwise, a potential sorting of workers with certain abilities or characteristics to firms exporting to certain destinations could bias our estimates of the effect on female relative wages. The worker and firm fixed effects, embedded in the match fixed effects, also deal with possible biases due to time-constant worker and firm characteristics, for example, individual worker ability or firm wage-setting practices. Additionally, the firm–year fixed effects deal with firm-specific shocks, for example, import supply shocks or financial shocks in a given year which, if not accounted for, would confound the estimate of β. Overall, our identification strategy relies on the assumption that after controlling for match and firm–year fixed effects and observable worker characteristics, other shocks that could impact workers' wages are orthogonal to a firm's choice of export destinations and export behavior in these destinations. Hence, the key identifying assumption we make is that firms' export patterns (as captured by *GIWS*) are unrelated to other time-varying gender-specific shocks to wages.

The fact that we exploit the variation in wages from within employer–employee match keeps the within-firm gender composition constant; it allows us to study what happens to the within-firm gender wage gap when exports to gender-unequal partners intensify. Concerns about reversed causality and endogeneity of exports are mitigated in our setting since firm export decisions are unlikely to be influenced by a single worker. To estimate the empirical regression models with high-dimensional fixed effects, we use an algorithm developed by Correia (2016), which takes care of the dimensionality problem induced by the multiple levels of fixed effects.

In addition to the match and firm–year fixed effects, we include control variables at the individual level, denoted by $\mathbf{X}_{it}$, that vary over time. The vector includes the potential labor market experience (*Experience*) and its square (*Experience*^{2}), a dummy variable for having children in the household between 0 and 18 years old (*Children*), and a dummy variable for working in a white-collar occupation (*White collar*). Control variables at the firm level, included in the vector $\mathbf{F}_{jt}$, are subsumed by the firm–year fixed effects unless interacted with the female dummy variable. Our baseline specification includes two such interactions: an interaction of the female dummy and firm export intensity, and an interaction of the female dummy and the log of firm sales. ε_{ijt} denotes the error term. The standard errors are clustered at the firm level.

In section 3, we display alternative specifications with even more granular fixed effects, which include occupations at the three-digit level. Specifically, we add firm–year–occupation fixed effects to adjust for heterogeneous effects across occupations within a firm. These fixed effects are intended to control for occupation-specific productivity shocks affecting a firm in a given year. Secondly, we include match–occupation fixed effects to care for workers switching occupations within the firm in response to a shock. However, the models with occupation-specific fixed effects are not considered our main specification since that might introduce bias to the estimates. Labor force adjustments within the firm, for example, workers switching occupations, serve as a potential mechanism through which changes in trade partners affect the gender wage gap. We return to this issue in section 3.

4 Data and Descriptive Statistics

4.1 Main Data Sources

In analyzing gender inequality at export destinations and exporters' gender wage gap, we use high-quality matched employer–employee data from Statistics Sweden, covering the years 1997–2015. The wage data we use stem from the Wage Structure Statistics (WSS), an annual labor force survey carried out by the Swedish National Mediation Office. From the survey, we get information on workers' full-time equivalent monthly wages in the survey month, as well as the contracted working hours. The monthly wage includes the agreed-upon wage plus amenities, bonuses, and variable incomes, but not over-time payments. The WSS survey covers all workers in private sector firms with 500 employees or more and more than 50 percent of the remaining workforce is surveyed every year. We also observe detailed occupational codes for the workers on a three-digit level.

We then match WSS survey information to the Structural Business Statistics (FEK), which yields a sample of approximately two million workers per year or half of all private sector employment. Due to the sampling of smaller firms in the wage survey, there are gaps in the data. Since an employee may be employed by another firm during the missing years, we do not impute values. From the FEK, we also collect information for all private non-financial companies on sales, profits, value-added, and industry affiliation.

Information on all workers and their socio-demographic characteristics, such as gender, age, education, and the number of children 0-18 years old, are gathered from the longitudinal integrated database for health insurance and labor market studies (LISA). The actual labor market experience is not available in LISA. Still, we use the available information to construct potential labor market experience as the difference between an individual's age and

i) the year since attaining the highest level of education or ii) the total years of education (based on the variable for highest attained education). In cases where neither of the education variables is available, we subtract 16 from an individual's age to measure the potential labor market experience.

Some data are also gathered on the plant level from the labor statistics based on administrative sources (RAMS), namely the location and the number of employees. The plant-level data are aggregated to the firm level. Information on firm-level export of goods comes from the Swedish Foreign Trade Statistics and is broken down by country of destination and the type of goods classification on an eight-digit level. The data cover all compulsory transactions registered by Swedish Customs: all export transactions of goods with countries outside the EU (Extrastat). Furthermore, data on trade with the EU countries are collected via a comprehensive population survey subject to a threshold. The threshold implies that the smallest firms are not included in the data collection procedure. Statistics Sweden complements the trade survey data with information from VAT declarations to the Swedish Tax Agency.

4.2 Sample Restrictions

To arrive at our baseline sample, we introduce some additional restrictions to the data. All workers between 18 and 67 years old are connected to the firm where they earned their highest yearly income using a unique identifier. Part-time workers may introduce biases to the estimate of the gender wage gap and are excluded from the analysis (Manning and Petrongolo, 2008; Albrecht et al., 2018).[11] To make a clear distinction between the effect of exporting and the effect of foreign ownership on female relative wages, we exclude foreign-owned firms from the baseline sample but include them in the analysis as a robustness test further on. After the sample restrictions mentioned above, we proceed by adding the measures of gender inequality of export destinations at the firm level.

4.3 The Gender Inequality Index

We measure gender inequality across countries with the well-established Gender Inequality Index (GII) constructed by the United Nations. The GII is available for most countries for the study period (1997–2015). There exists some variation in the availability of the index across years, but, as a general rule, we use the latest available data for each country by imputing values for the missing years. We believe that imputation is justified since we do not expect significant, sudden changes in the country's GII from one year to the next.

The GII embraces three distinct dimensions of gender inequality: health, empowerment, and labor market participation across genders. For each of

[11] Information on contracted hours is obtained from the WSS.

Table 1. *Descriptive Statistics: Raw GII*

Most Gender-Equal Countries			*Least Gender-Equal Countries*		
	Rank	Mean		Rank	Mean
Denmark	1	0.066	Brazil	41	0.481
Netherlands	2	0.079	Turkey	42	0.490
Switzerland	3	0.080	Algeria	43	0.525
Finland	4	0.082	Indonesia	44	0.542
Norway	5	0.088	Iran, Islamic Rep.	45	0.556
Belgium	6	0.107	Morocco	46	0.599
Germany	7	0.115	Egypt, Arab Rep.	47	0.607
Spain	8	0.117	Saudi Arabia	48	0.615
Austria	9	0.131	India	49	0.624
France	10	0.137	Pakistan	50	0.644
Sweden		0.054			
OECD		0.259			
World		0.495			

Note: The ranking is based on the 50 largest export destination countries for Swedish exporting firms over the 1997–2015 period. The reader can find the complete list of Sweden's 50 largest export destinations and their corresponding gender indices in Table A1 in the Appendix.

these overarching areas, different indicators are used as building blocks to arrive at the broad and representative metric of gender inequality across countries. The health indicators include maternity mortality ratio and adolescence birth rate; the empowerment indicators include the female and male populations with at least secondary education and female and male share of parliamentary seats; and, for the labor market participation, the measures of female and male labor force participation rates are used. From the indicators mentioned above, a separate gender inequality index is built for males and females, a combination of which yields the GII. A higher value of the GII implies that a higher gender inequality characterizes a country.

To illustrate the extent of gender inequality that Swedish exporters in our sample are exposed to, Table 1 ranks Sweden's 50 largest export destinations according to their raw GII value. As expected, other Nordic and Western European countries remain among the ten most gender-equal Swedish export destinations. On the other hand, countries in Asia, Africa, and South America are among Sweden's least gender-equal trade partners. Importantly, we use all Swedish export destination countries when constructing our empirical gender indices. In contrast, countries in Table 1 are only meant to illustrate the spectrum of gender inequality that Swedish exporters are exposed to through their international operations.[12]

4.4 Descriptive Statistics

Table 2 shows the descriptive statistics for the firm-level variables in Panel A, and the worker-level variables in Panel B. Firm size is defined as the total number of employees attached to the firm in our sample, and the mean firm size is 196 employees. To obtain the export intensity variable, we divide total goods exports by total sales. Panel A demonstrates that the mean export intensity among the analyzed firms is 21 percent, while the median export intensity is 6 percent. The female share of the labor force is the number of female workers through the total number of workers in the firm. It is 26 percent at the mean and 20 percent at the median, suggesting that most firms we study are male-intensive. We observe 5,171 unique firms in the sample, yielding 24,954 firm–year observations.

Summary statistics of the gender indices are also presented in Panel A in Table 2. The mean (median) export-weighted gender inequality index *GII* is 0.15 (0.12), while the mean (median) gender-inequality-weighted sales *GIWS* is 0.08 (0.06). Figure 1 displays the distribution of the *GII* in our sample, which appears right-skewed, with the bulk of observations below 0.4. Figure 2 instead shows the distribution of *GIWS*, which is even more right-skewed with a thin tail of large *GIWS* values. Most firms in our sample exhibit a value of *GIWS* below 0.3.

Panel B in Table 2 displays the average sample values of the worker-level variables. The average monthly wage is €3,299, and the gender wage gap is about 10 percent. On average, women earn €3,056, whereas men earn €3,373. Female workers are slightly younger and less experienced than their male colleagues. The share of workers with children below 18 years old is 0.43, with no significant difference across genders. Furthermore, 17 percent of the workers in the sample have attained a college degree. This number is 21 percent among women, and 15 percent among men, indicating that women, on average, are more educated than their male colleagues. Female workers tend to be much more represented in white-collar occupations, with 64 percent, as opposed to their male counterparts, with 46 percent. For the analysis, the total number of workers we observe is 830,031, which yields 4,895,953 worker–year observations. As indicated above, the sample consists of more male workers (610,271) than female workers (219,760), reflected in the worker–year observations being around 3.8 million for men and 1.1 million for women.

[12] Table A1 in the Appendix lists all 50 destination countries receiving the largest share of Swedish exports, ranked based on the raw GII value.

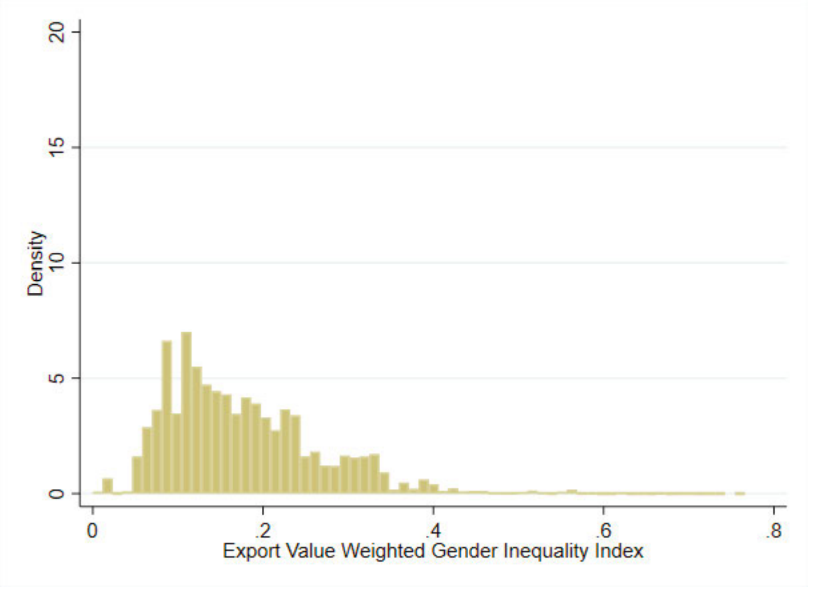

Figure 1. Export-Weighted Gender Inequality Index

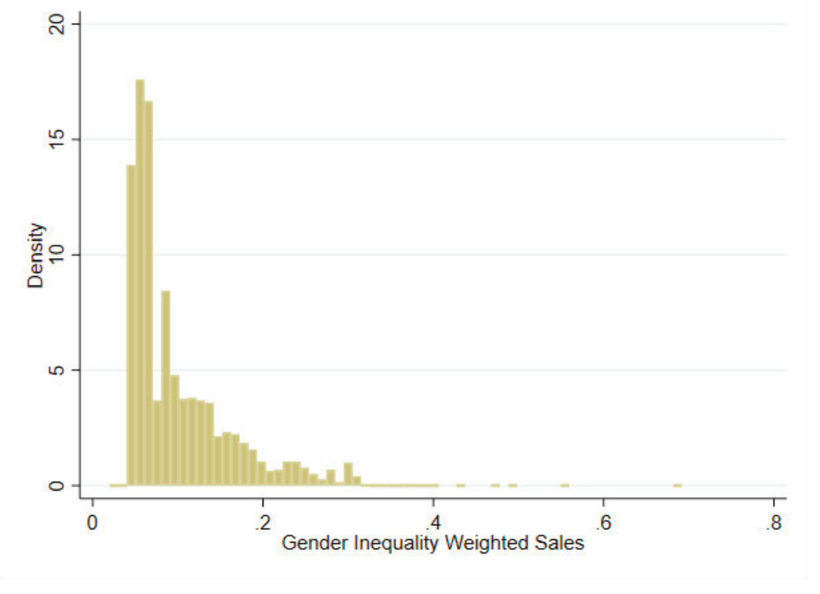

Figure 2. Export-Weighted Gender Inequality Weighted Sales

Table 2. *Descriptive Statistics*

Panel A. Firm-level Statistics	Mean	Median	SD
Firm size (number of employees)	196	763	899
Sales (mln €)	7,629	969	35,909
Export/Sales	0.21	0.06	0.27
GII	0.15	0.12	0.09
GIWS	0.08	0.06	0.04
Female share of labor force	0.26	0.20	0.19

Panel B. Individual-level Statistics	All	Female	Male
Monthly Wage (€)	3,299	3,056	3,373
Monthly Wage (log)	8.04	7.97	8.06
Experience	21.02	19.73	21.41
Age	42.09	41.52	42.26
Share with children	0.43	0.42	0.43
Share with college education	0.17	0.21	0.15
Share of white-collar workers	0.51	0.64	0.46
Share of blue-collar workers	0.49	0.36	0.54
Number of individuals	830,031	219,760	610,271
Number of individual−year obs	4,895,953	1,139,217	3,756,736

Notes: On the firm level, all numbers are based on the panel of firm-level data in our sample of domestic exporting firms for 1997–2015. On the individual level, all numbers refer to average values of the indicated variables for the panel of worker-level data for 1997–2015.

5 Results

5.1 GIWS and the Gender Wage Gap

To establish whether gender inequality can spread through international trade and impact the gender wage gap in exporting firms, we start with the model outlined in equation (8), where we regress log wages on the $GIWS$ measure. Table 3 displays the main results, and in column (1), we document an estimated coefficient of Female×GIWS of -0.195. Since $GIWS$ captures firm exposure to gender inequality through its total sales, we augment the model with an interaction of export intensity and the female dummy. In column (2), Female×Export is intended to control for the direct effect of exports on female relative wages, along with the $GIWS$.[13] When directly controlling for export

[13] We prefer the model specification in column (2) in Table 3 to its alternatives and will refer to it as our main, or baseline, specification throughout the rest of the paper.

intensity, we find a slightly more negative estimate of Female×GIWS, -0.25. The negative estimate implies that the gender wage gap increases when firms export a larger proportion of their total sales to gender-unequal destinations. To make sense of the magnitude, a 10 percentage point increase in *GIWS* (an increase in *GIWS* of 0.1) would yield an estimated 2.9 percent decrease in female relative wages. Putting it in context, if a firm that used to export all of its sales to Denmark (ranked number one in Table 1) would now export all of its sales to Saudi Arabia (ranked 48 in Table 1), the average female relative wage would decrease by approximately 14 percent.

Table 3. *Main Results: GIWS*

Dep. var: ln(Wage)	(1)	(2)	(3)	(4)
Female×GIWS	-0.195***	-0.250***	-0.146***	-0.117***
	(0.025)	(0.036)	(0.023)	(0.021)
Female×Export		0.019***	0.0001	0.003
		(0.009)	(0.011)	(0.009)
Match FE	yes	yes	yes	no
Firm×Year FE	yes	yes	no	no
Firm×Year×Occup. FE	no	no	yes	yes
Match×Occup. FE	no	no	no	yes
Adj. R^2	0.93	0.94	0.93	0.95
Observations	4,895,953	4,895,953	4,812,942	4,433,872

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. When constructing occupational fixed effects, missing occupations are grouped into one category. Additional control variables included in all specifications are Experience, Experience^2/100, White Collar, Children, and Female×ln(Sales). Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

To control for occupation-specific shocks within the firm and to remove any changes in the gender wage gap mediated through this channel, we add firm–year–occupation fixed effects in column (3). The estimated impact of *GIWS* is reduced to -0.146, indicating that some of the overall negative impact of *GIWS* stems from shocks to particular occupations, making men and women differently exposed. Referring to the previous example, a swap in exclusive exporting from Denmark to Saudi Arabia would decrease female relative wages by around 8 percent, according to the estimated effect in column (3). The fact that the average effect on female relative wages might hide substantial heterogeneity across occupations urges us to investigate this channel in greater detail in section 5.2, where we pay particular attention to female managers.

As outlined in section 3.2, a final extension of the main model is the inclusion of match–occupation fixed effects in column (4) in Table 3. The model with match–occupation fixed effects and firm–year–occupation fixed effects represents our most stringent specification. In this specification, we only compare the wages of female and male colleagues working at the same firm and holding the same occupation over time, in addition to controlling for occupation-specific shocks affecting the firm. The model with an extensive number of fixed effects is very restrictive. However, it still underlines our previous finding: the estimated coefficient on female relative wages, -0.117, is similar to the estimate in column (3).[14] One should remember that the specifications with occupational fixed effects are very demanding on the data and leave us with a thin level of variation in wages. Additionally, since switching an occupation might be an outcome of its own, restricting workers to stay in the same occupation might potentially introduce bias to the estimated effects and should therefore be interpreted with caution. For these reasons, we keep the specification in column (2) as our main specification throughout the paper.[15]

An important control variable included in all specifications is the interaction term between the female dummy and the firm sales in log form. The variable aims to capture if men and women have different bargaining power (θ) and, thus, if rents are shared differently across genders. As shown in Table A2 in the Appendix, the interaction term lacks statistical significance in all specifications. This result confirms that the theoretical assumption of similar bargaining power of men and women holds, at least in our sample.

In Table 3, all the estimated coefficients of Female$\times$GIWS are statistically significant at the one percent significance level. The estimated effects also display non-trivial magnitudes, with large economically meaningful effects for workers most exposed to gender inequality on behalf of trading partners.[16]

5.2 Female Managers

The negative average impact of *GIWS* on female relative wages identified in section 5.1 may potentially hide substantial heterogeneity across occupational groups. We explore this in Table 4, where workers are divided into three occupational categories: managers, other white-collar workers, and blue-collar workers. As seen in column (1), the negative effect on female managers' wages is substantial and more pronounced than the effect on other white-collar workers in column (2), also when considering the precision of the estimated effects. We explain the observed strong response in manager wages by managers being more involved in exporting activities and communication with for-

[14] The sample size decreases somewhat between columns (2) to (3) in Table 8, and even more so between columns (3) to (4). The reason behind the reduction in sample size is that some occupations may not be present in a firm for more than one year or that workers are only observed in the same occupation in a given firm for only one year.

[15] Table A2 in the Appendix displays additional fixed-effects specifications and estimates for all control variables included in the model.

[16] The insensitivity of our findings to different levels of clustering of the standard errors is shown in Table A3 in the Appendix. A higher level of clustering of the standard errors at the 2-digit industry level still yields statistical significance at the 1 percent level.

eign customers, and hence more exposed to potential gender inequality and customer discrimination. For other female white-collar workers, the negative wage effect is about a third as large as the estimated effect on female managers' wages. We detect no significant impact of increased exports on the relative wages of female blue-collar workers, as indicated in column (3).

Table 4. *Occupations*

Dep. var: ln(Wage)	Managers (1)	Other White Collar (2)	Blue Collar (3)
Female×GIWS	-0.341***	-0.119***	-0.048
	(0.122)	(0.029)	(0.042)
Female×Export	0.024	-0.013	0.005
	(0.034)	(0.015)	(0.007)
Match FE	yes	yes	yes
Firm×Year FE	yes	yes	yes
Adj. R^2	0.96	0.94	0.81
Observations	280,241	2,131,867	2,405,140

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. The sample is split into three groups based on the worker's occupation: managers (1), other white-collar workers (2), and blue-collar workers (3). Additional control variables included in all specifications are Experience, Experience$^2/100$, Children, and Female×ln(Sales). Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

The evidence in Table 4 is conclusive: female managers tend to be most affected when the firm exports increasingly to gender-unequal destinations. The effect we find for the other white-collar category indicates that workers in other occupations, possibly the ones interacting with customers, also tend to be influenced by gender-biased export partners, forcing their wages to decline with more exposure. Our findings are reminiscent of the emerging literature on glass ceiling effects for women and gender gaps in promotions due to internationalization.[17]

5.3 Export Partner Gender Inequality and the Gender Wage Gap: An Alternative Empirical Model

The *GIWS* measure, used in the empirical model in section 3.2, assumes a certain structure of how gender (in)equality of foreign partners and gender

[17] See, e.g, Heyman et al. (2018)

equality of domestic partners translates to female relative wages. In this section, we reformulate the empirical model slightly to obtain a more direct effect of exports on wages, depending on the gender inequality of the destination country. The model is otherwise similar to equation (8), but the double interaction Female×GIWS is now replaced with a triple interaction of the female dummy, firm export intensity, and the export-weighted gender inequality index, GII. The log wage of individual i working at firm j at time t is now given by:

$$\begin{aligned} w_{ijt} = &\beta_1[Female_i \times EI_{jt} \times GII_{jt}] \\ &+ \beta_2[Female_i \times EI_{jt}] \\ &+ \beta_3[Female_i \times GII_{jt}] \\ &+ \mu_{ij} + \eta_{jt} \\ &+ \mathbf{X}'_{it}\gamma + \mathbf{F}'_{jt}\phi \\ &+ \varepsilon_{ijt} \end{aligned} \tag{9}$$

where the main coefficient of interest is the slope coefficient of the three-way interaction, β_1, indicating a combined effect of export intensity and gender inequality on female relative wages. Moreover, β_2 measures the impact of increased export intensity on female relative wages, evaluated at the mean GII, and β_3 is the coefficient of the interaction between the female dummy and the export-weighted gender inequality index. The wage equation in (9) is otherwise specified exactly as in equation (8) with employer–employee match fixed effects, μ_{ij}, and firm–year fixed effects, η_{jt}. Advantageously, equation (9) allows us to visualize the marginal effects in a figure, illustrating the estimated effects of increased export intensity on wages for various levels of the GII.

The estimated effects from equation (9) are shown in Table 5. In column (1), we first display the average effect on female relative wages from increased export intensity, which is not interacted with the export-weighted gender inequality index. The estimated coefficient (-0.029) aligns with the effects found earlier in the literature.[18] Specifically, if a firm shifts all of its sales from the domestic market to the international market, female relative wages would, on average, decrease by approximately 3 percent. This finding suggests that increased export intensity, on average, leads to a wider gender wage gap.

In column (2) in Table 5, we add the triple interaction with the GII to establish whether the average export effect differs across the level of gender equality of destination countries. The coefficient of the three-way interaction is -0.235, which corresponds to a 13 percent decrease in female relative wages if a firm exporting all of its sales shifts its destination from Denmark to Saudi Arabia. Column (2) also displays the estimates of the double interactions Female×Export and Female×GI, but they are small in magnitude and not statistically significant. All specifications in Table 5 include the standard

[18] See Bøler et al. (2018) for results for Norway, and Halvarsson et al. (2022) for Sweden.

employer–employee match and firm–year fixed effects. As before, specifications in columns (3) and (4) are augmented with firm–year–occupation and match–occupation fixed effects, respectively. Once occupational fixed effects are added, the corresponding three-way interaction estimates are -0.138 and -0.100 in columns (3) and (4), respectively.[19]

Table 5. *Alternative Model: GII*

Dep. var: ln(Wage)	(1)	(2)	(3)	(4)
Female×Export×GII		-0.235***	-0.138***	-0.100***
		(0.037)	(0.022)	(0.020)
Female×Export	-0.029**	-0.011	-0.014	-0.012
	(0.014)	(0.007)	(0.009)	(0.008)
Female×GII		-0.007	0.001	0.005
		(0.007)	(0.006)	(0.006)
Match FE	yes	yes	yes	no
Firm×Year FE	yes	yes	no	no
Firm×Year×Occupation	no	no	yes	yes
Match×Occupation	no	no	no	yes
Adj. R^2	0.93	0.93	0.94	0.95
Observations	4,895,953	4,895,953	4,812,942	4,433,872

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. When constructing occupational fixed effects, missing occupations are grouped into one category. Additional control variables included in all specifications are Experience, Experience^2/100, White Collar, Children, and Female×ln(Sales). Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Figure 3 illustrates the negative effect on female relative wages from intensified exports to gender-unequal destinations—the main result from column (2) in Table 5. In addition to the point estimates and the 95 percent confidence bounds, Figure 3 also plots the density of the export-weighted gender inequality index. We observe a few spikes among the more gender-equal parts of the distribution (to the left) and a slight decrease of the mass towards the most gender-unequal parts of the *GII* distribution (to the right). In Figure 3, we hold the *GII* constant and only allow the export intensity to vary. Hence, an increase in export intensity generates a negative but not statistically significant point estimate of around -0.01 when measured at the mean level of the gender inequality index (0.15).[20]

[19]Table A4 in the Appendix displays our findings for the *GII* model with the three-way interaction across different levels of fixed effects, as well as estimates of all the control variables included in the models.

[20]The estimate corresponds to the coefficient for Female×Export in column (2) of Table 5, where the *GII* is held constant at its mean sample value.

Figure 3 clearly illustrates that there are no wage effects from increased exports to gender-equal countries (the left tail of the *GII* distribution). However, when exports to gender-unequal countries surge (the right tail of the *GII* distribution), female relative wages appear to fall. The strong response from exports to gender-unequal destinations explains the overall negative effect we have previously established on female wages. Taken together, the results show that intensified exports to gender-biased countries generate statistically significant wage penalties for female workers, which sheds further light on the mechanisms at play.[21]

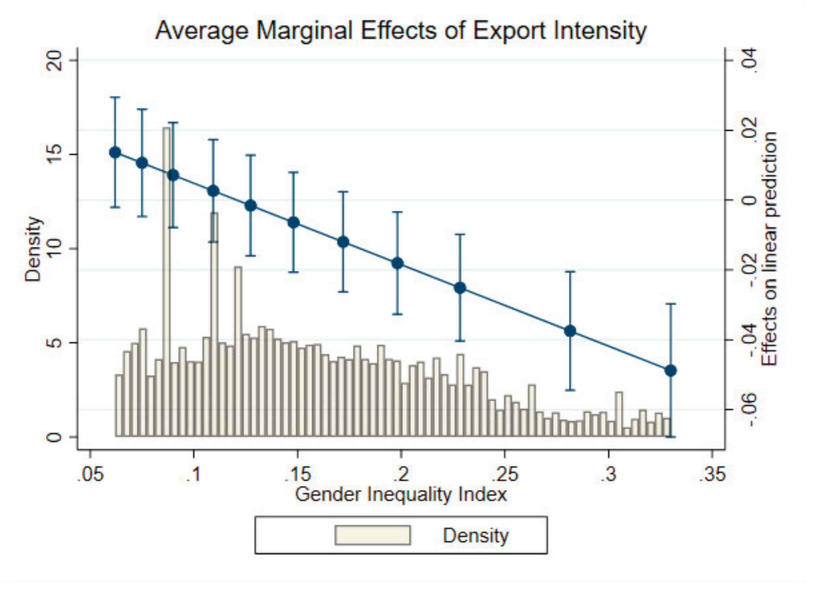

Figure 3. Export-Weighted Gender Inequality Index

5.4 Robustness

To investigate our findings' robustness, we apply various restrictions to the baseline sample. In column (1) in Table 6, we estimate the benchmark model on a sample of large firms, that is, firms with at least 50 employees. Notably, only about 250,000 observations in the sample of 4.9 million observations belong to firms with less than 50 employees in our sample. As expected, excluding small firms leaves the main estimated effect essentially unchanged. We move on by excluding workers with less than five years of tenure at a firm

[21]Figures A1 and A2 in the Appendix show marginal effects from non-linear, quadratic, and cubic specifications of equation (9). We also present results from using a standardized version of the *GII* in Table A5 and Figure A3 in the Appendix. The findings do not appear to be sensitive to the functional form of the gender inequality index.

to test whether the adverse wage effect we find could be driven by newly hired workers or workers with short tenure. The estimate in column (2) rules out this possibility. If anything, the results are stronger for workers staying longer at the firm. This finding relates to the literature on managers' earlier experiences and firm export patterns.[22] If the identified effect only stemmed from a new manager entering the firm and changing both firm export decisions and wages, it is unlikely that we would find an even stronger effect when excluding newly hired employees.[23]

In column (3), we consider only manufacturing firms, for which we find that the effect of increased exposure to gender inequality is approximately the same magnitude as before. In column (4), we almost double the estimation sample by including foreign-owned firms.[24] The impact on female relative wages becomes slightly less pronounced, with a coefficient of -0.22 compared to -0.25 in our main specification in column (2) in Table 3. Despite the slightly attenuating effect when including foreign-owned firms, we deem our main finding robust to firm ownership status. In column (4), we exclude firms with less than 10 percent of female workers to establish whether firms with low female worker shares drive our findings. In a similar vein, we exclude firms with less than 10 percent of women among managers in column (5). As apparent from Table 6, our findings are insensitive to the exclusion of firms with a low share of female workers or a low share of female managers.

Table 6. *Robustness I: Sample Restrictions*

Dep. var: ln(Wage)	Empl.>= 50 (1)	Tenure>= 5 (2)	Manufacturing (3)	Fng incl. (4)	Fem. Share> 0.1 (5)	Fem. Manager> 0.1 (6)
Female×GIWS	-0.262***	-0.293***	-0.260***	-0.220***	-0.219***	-0.223***
	(0.037)	(0.046)	(0.035)	(0.029)	(0.034)	(0.033)
Female×Export	0.021**	0.031**	0.017*	0.019***	0.012	0.009
	(0.010)	(0.015)	(0.009)	(0.006)	(0.009)	(0.015)
Match FE	yes	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes	yes
Adj. R^2	0.93	0.95	0.94	0.93	0.94	0.95
Observations	4,635,036	1,888,065	2,585,525	9,115,603	4,235,337	2,869,597

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. The following sample restrictions are applied, as indicated by the column headings: firms with more than 50 employees (1); employees with five or more years of tenure at the firm (2); manufacturing firms (3); both domestic and foreign-owned exporting firms (4); firms with more than 10% of female workers (5); firms with more than 10% of female managers (6). Additional control variables included in all specifications are Experience, Experience^2/100, Children, College, White collar, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

In sum, Table 6 provides conclusive evidence that the estimated effects are stable under different sample restrictions. The solid pattern across specifications in Table 6 makes us confident in our main conclusion: when firms intensify their sales to gender-unequal destinations, the female relative wages decrease, yielding an increase in the within-firm gender wage gap.

[22] See, e.g., Mion et al. (forthcoming) and Meinen et al. (2022).

[23] Table A6 in the Appendix provides more results across employment tenure groups.

[24] See Appendix Table A7 for results when the sample is split by firm ownership status.

Irregular Export Behavior

A potential concern is that firms' irregular export behavior might generate attenuation bias to our findings. It is well recognized that many exporting firms sell abroad at low intensity, with export values close to zero.[25] As illustrated by Figure 4, we observe a similar pattern in our sample, where a handful of firms exhibit moderate to small export intensity. To account for that, in Table 7, we focus on firms following more stable exporting patterns and exclude firms hovering just around the zero export value.

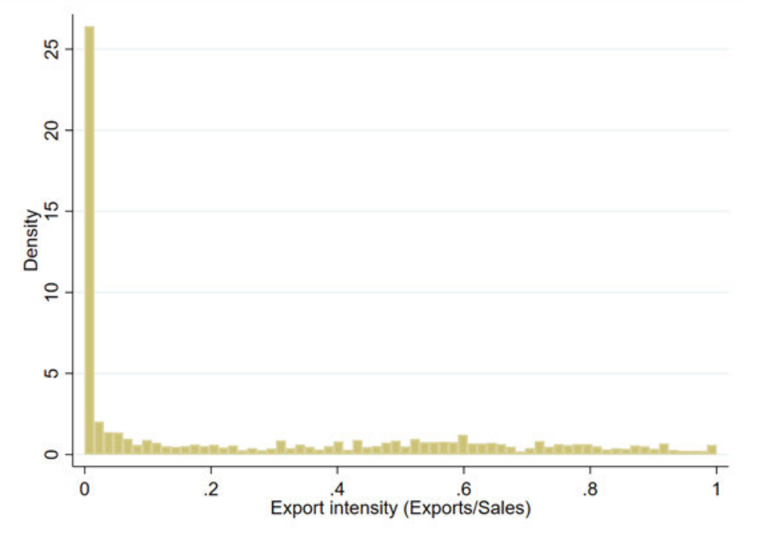

Figure 4. Density of Export Intensity

In Table 7, each column subsequently excludes firms with the lowest degree of export intensity. Leaving out firms with export intensity below one percent cuts the sample by approximately two million observations and removes the spike just above zero in Figure 4. In columns (2) and (3), firms below two and three percent export intensity are excluded, respectively, and in column (4), we remove firms with less than five percent of their total sales abroad. Finally, column (5) omits firms with an export intensity below ten percent. The impact of intensified trade with gender-unequal partners remains largely unaffected. The coefficient of Female$\times$GIWS is -0.235 in column (1) and stays around this magnitude throughout Table 7. Similarly, the precision of the estimated effect also remains intact throughout this robustness exercise. Noteworthy, we observe a large drop in observations as we move from the baseline sample in Table 3 to the restricted sample in column (1) in Table 7, but further restrictions of the sample do not alter the number of observation in any significant way. For example, going from a one percent cutoff in column (1) to a ten percent

[25] As before, we measure export intensity as a fraction of exports to total sales.

cutoff in column (5) only generates a loss of approximately 560,000 worker–year observations. In general, the sensitivity analysis of firm export behavior largely confirms our previous findings.[26]

Table 7. *Robustness II: Export Intensity*

	Exclude if Export Intensity Below				
	[0.01]	[0.02]	[0.03]	[0.05]	[0.1]
Dep. var: ln(Wage)	(1)	(2)	(3)	(4)	(5)
Female×GIWS	-0.235***	-0.234***	-0.233***	-0.235***	-0.237***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.034)
Female×Export	0.015*	0.014*	0.014	0.014	0.014
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Match FE	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes
Adj. R^2	0.94	0.94	0.94	0.94	0.94
Observations	2,967,699	2,838,820	2,755,461	2,618,544	2,402,701

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. Additional control variables included in all specifications are Experience, Experience$^2/100$, White Collar, Children, and Female×ln(Sales). Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Alternative Gender Indices

In this section, we investigate whether our main findings are sensitive to the choice of the gender index. We start by replacing the GII with the GGI—a composite measure of gender equality from the World Economic Forum. The GGI is available from 2006 onward and is intended to measure the extent of gender equality at the country level. The index covers four main themes: economic participation and opportunity, educational attainment, health and survival, and political empowerment. An essential difference between the GII and the GGI is that the latter does not account for women being better off than men in any area.[27] To make the two indices comparable, we reverse the values of the GGI such that larger values of the index reflect a higher level of gender

[26] For the sensitivity analysis of the *GIWS* measure, see Table A8 in the Appendix, where we winsorize and trim the variable.

[27] The construction method of the GGI implies that areas, where women are better off compared to men, will not discount the areas where women are worse off compared to men. For example, women having a higher share of seats in parliament does not compensate for the skewed educational attainment in favor of men. The conceptual differences in the construction of the indices influence their distributions such that countries look more gender-unequal as measured with the GGI compared to the GII. Figure A4 in the Appendix shows the distribution of the (reversed) GGI. Furthermore, the correlation between the two export-weighted gender indices is 0.75 in our sample.

inequality. Similar to the GII, we impute values for missing years to utilize the full range of employer–employee observations in our sample.

Column (1) in Table 8 corresponds to column (2) in Table 3 in section 5.1, but now the *GIWS* is constructed with the GGI instead of the GII. The estimated coefficient of Female×GIWS is -0.393 in column (1).

Table 8. *Robustness III: Alternative Gender Indices*

	GGI	GII Subindices			
		LFP	Empowerment	Seats in Parliament	Secondary Educ.
Dep. var: ln(Wage)	(1)	(2)	(3)	(4)	(5)
Female×GIWS	-0.393***	-0.420***	-0.132***	-0.132***	-0.099***
	(0.096)	(0.101)	(0.027)	(0.036)	(0.017)
Female×Export	0.012	0.008	0.008	0.006	-0.013
	(0.009)	(0.009)	(0.013)	(0.015)	(0.011)
Match FE	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes
Adj. R2	0.93	0.93	0.93	0.93	0.93
Observations	4,895,899	4,895,953	4,895,953	4,895,953	4,895,953

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. Subindices of the GII, pertaining to women and indicated in the column headings, are used to construct the GIWS measure. The values of the GGI and the GII subindices are reversed to match the interpretation of the baseline measure. Additional control variables included in all specifications are Experience, Experience$^2/100$, Children, College, White collar, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

In addition to the GGI, we also control whether our results hold under alternative measures of gender inequality. Specifically, in columns (2)-(5) in Table 8 we present the results using four sub-indices of the GII. Labor force participation (LFP) in column (2) is the reversed female labor force participation rate (1 - Female LFP) to keep the same interpretation as for the overall GII and GGI, where higher values imply less equality. Likewise, Empowerment in column (3) is the reversed measure of female empowerment, which combines the other two indicators - Seats in parliament and Secondary education. The reversed measures of female share of seats in parliament and female secondary education are included separately in columns (4) and (5) in Table 8.

The main takeaway from Table 8 is that it does not seem to matter for the main conclusion exactly which measure of gender inequality one uses. Hence, using an alternative gender index in the construction of the exposure measure provides qualitatively similar estimates and thus further confirms our findings.

5.5 Relation to Mechanisms in the Previous Literature

The previous literature on exports and the gender wage differential has highlighted several mechanisms that may explain why exporters would favor male worker wages. To account for this evidence, we in Tables 9, 10, and 11 sequentially control for channels underlined in the related research to establish whether the mechanism proposed in this paper—gender inequality at export destinations—still matters.

We start by examining the mechanism suggested by Bøler et al. (2018), in which female workers are penalized by exporters due to the lack of flexibility in working hours and commitment. First, we exclude workers who may experience more time constraints than others. The categories of excluded workers in Table 9 are i) workers with children aged 0–6 (column (1)), ii) workers with children aged 0–18 (column (2)), and iii) workers under the age of 45 (column (3)). In essence, we leave out workers with children and young workers who are more likely to plan for children and may therefore opt for jobs offering flexible working arrangements. Throughout columns (1)–(3), we observe that workers with children, or young workers below the age of 45, are not driving our findings.

Table 9. *Worker Temporal Flexibility*

Dep. var: ln(Wage)	No Child 0-6 (1)	No Child 0-18 (2)	Age>44 (3)	BHO (4)	Time Zone FE (5)
Female×GIWS	-0.296***	-0.279***	-0.299***	-0.249***	-0.251***
	(0.032)	(0.031)	(0.027)	(0.036)	(0.036)
Female×Export	0.029***	0.031***	0.029***	0.018**	0.019**
	(0.009)	(0.007)	(0.010)	(0.009)	(0.009)
Match FE	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes
Time Zone FE	no	no	no	no	yes
Adj. R2	0.94	0.93	0.96	0.93	0.95
Observations	3,884,669	2,752,158	2,059,343	4,895,953	4,895,953

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. Column headings in (1)-(3) indicate the group of workers included in the analysis. The business hours overlap index as constructed by Bøler et al., 2018 is included as a control variable in column (4), and a set of time zone fixed effects interacted with the female dummy variable are included in column (5). Additional control variables included in all specifications are: Female×ln(Sales), Experience, Experience^2/100, and White Collar. Robust standard errors clustered at firm-level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We continue controlling for the flexibility hypothesis in column (4) in Table 9. Specifically, we add the business hours overlap (BHO) index following Bøler et al. (2018), which is intended to account for the temporal flexibility required by exporting firms when operating across different time zones. Similar to their measure, the BHO index is constructed at the firm level as a trade-weighted average of the BHO, where the weights are the number of products exported to each time zone. Essential for our conclusions, the effect of trading with gender-biased customers stays intact when controlling for the BHO index.

In column (5), we add time zone fixed effects to address the same concern as with the BHO index. Adding fixed effects for the time zones a firm trades with times a female dummy does not change the effect of Female×GIWS. The findings in Table 9 indicate that although we control for female temporal flexibility in different ways, there is still a significant effect from trading with gender-biased customers.

We continue to test for other mechanisms that could be at play in Table 10. Column (1) displays the baseline estimate of Female×GIWS found earlier in Table 3. In column (2), we augment the model with the contract intensity index, which is shown to affect the gender wage gap in globalized firms (Halvarsson et al., 2022). The contract intensity index after Nunn (2007) reflects the share of differentiated, as opposed to homogeneous, goods exported by a firm and intends to capture the extent of interpersonal contact needed in international transactions. The contract intensity index is a time-fixed index at the industry level, and therefore similar to all firms in the same industry. Goods contract intensity appears to exert a negative and statistically significant effect on female relative wages but yields no changes to the estimate of Female×GIWS, compared to the baseline estimate in column (1).

Table 10. *Other Mechanisms*

Dep. var: ln(Wage)	Baseline (1)	CI Index (2)	Profitability (3)	GDP (4)	Imports (5)
Female×GIWS	-0.250***	-0.229***	-0.252***	-0.246***	-0.252***
	(0.036)	(0.042)	(0.036)	(0.035)	(0.036)
Female×Export	0.019*	0.022***	0.020**	0.018*	0.019**
	(0.009)	(0.008)	(0.009)	(0.009)	(0.009)
Female×Export×CI		-0.062**			
		(0.030)			
Female×ln(Profitability)			-0.001*		
			(0.000)		
Female×GDP				0.000***	
				(0.000)	
Female×ln(import)					0.000
					(0.001)
Match FE	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes
Adj. R^2	0.93	0.93	0.93	0.93	0.93
Observations	4,895,953	4,895,953	4,895,953	4,895,953	4,656,233

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. Additional control variables are added to the model as indicated by the column headings: (1) Baseline, (2) the Contract Intensity Index, (3) ln(Profitability), (4) GDP of export destinations, and (5) ln(Imports). Additional control variables included in all specifications are Experience, Experience^2/100, Children, College, White collar, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

A firm-level measure of profitability is added in column (3) to address the issue that men tend to claim higher rents than women as a firm becomes more profitable (see, e.g., Card et al. (2016)). Controlling for firm-level profitability does not alter our main result in any significant way. Noteworthy is that we already include a control variable for unequal rent sharing between men and women, Female×ln(sales), in all specifications. The interaction variable should already capture if men and women gain differently from increases in firm sales. As shown in column (3), adding an additional gender-specific control for profitability on top of this does not alter the estimated effect of Female×GIWS compared to the baseline.

Table 11. *Trade Within and Outside of the European Union and Norway*

Dep. var: ln(Wage)	GII (1)	GGI (2)
Female×GII(EU)×Export(EU)	-0.287**	-0.456***
	(0.129)	(0.156)
Female×GII(nonEU)×Export(nonEU)	-0.254***	-0.332**
	(0.064)	(0.151)
Female×Export(EU)	-0.014*	-0.003
	(0.008)	(0.009)
Female×Export(nonEU)	0.001	-0.001
	(0.015)	(0.015)
Female×GII(EU)	-0.065**	-0.154***
	(0.031)	(0.037)
Female×GII(nonEU)	-0.007	-0.002
	(0.005)	(0.007)
Match FE	yes	yes
Firm×Year FE	yes	yes
Adj. R^2	0.93	0.93
Observations	3,947,762	3,947,762

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. Additional control variables included in all specifications are Experience, Experience$^2/100$, Children, College, White collar, and Female×ln(Sales). Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Another potential concern is that GIWS might reflect the general development of the economy at export destinations rather than its gender norms and equality. To test that, we augment the model with an export-weighted GDP of the firm's export partners. As apparent from column (4), we do not find any evidence that our exposure measure, *GIWS*, captures the overall economic development rather than the level of gender inequality of the trade partners. Finally, in column (5), we add the log of imports to account for the potential role it might have in shaping the gender wage gap.[28] This robustness check does not disturb our earlier findings.

Table 11 investigates if the geographical distance between Swedish firms and their export destinations drives our findings. We examine this possibility by dividing total exports into exports to the European Union and Norway and exports to the rest of the world. Suppose it is indeed gender inequality, rather than distance, standing behind our findings. In that case, we expect to obtain negative and statistically significant effects of exports to the EU countries on female relative wages. The coefficients are -0.287 and -0.254 for EU and non-EU exports in column (1), where results using the GII are presented. In column (2) a similar three-way interaction regression model is estimated, with the only difference that we replace GII with GGI to ensure that the choice of gender index is not driving this finding. The results in Table 11 confirm our hypothesis and show that both exports to gender-unequal countries within and outside the EU yield a wider gender wage gap.

Taken together, the results from Tables 9, 10, and 11 confirm that the mechanism we identify is robust to the alternative explanations, and that gender inequality transferred from export destinations appears to non-trivially contribute to the gender wage gap in globalized firms.

6 Conclusions

We evaluate the impact of gender inequality at export destinations on the gender wage gap in exporting firms. To construct the firm-level measure of exposure to gender inequality of trading partners, we utilize the well-established gender inequality index by the United Nations. To guide our analysis, we outline a stylized partial equilibrium model showing how customer discrimination on behalf of export partners may spill over to female wages in exporting firms, even if these firms are otherwise gender-equal.

In the empirical analysis, we document that increased export to gender-unequal destinations widens the gender wage gap in exporting firms. The finding is of clear economic importance: if a firm shifts all of its sales from the most gender-equal destination in our sample (Denmark) to one of the most gender-unequal destinations (Saudi Arabia), female relative wages decrease by approximately 14 percent. In addition, we document an average negative effect of increased exports on female relative wages. The average negative effect is, however, entirely driven by firms working with gender-biased partners; for firms exporting mainly to countries of similar equality levels, we detect no impact on the gender wage gap. The main finding is robust to different model specifications, sample restrictions, and alternative measures of gender inequality.

[28] See Khoban (2021) on the impact of firm imports on female labor market outcomes in Indian firms.

We show that the estimated negative effect on female relative wages is most pronounced for female managers. A possible explanation behind this finding is that managers are more exposed to gender inequality at export destinations through their communication with foreign partners and involvement in exporting activities. Although we also find adverse effects for other female white-collar workers, these are only about a third as large as the effects for managers. For female blue-collar workers, the effects are small and insignificant.

As a final note, the proposed stylized model represents partial equilibrium in a subset of firms meaning that the effects we identify for the exporting firms correspond to a lower bound of the general equilibrium estimates. In a general equilibrium setting, the decreasing female relative wages from exports to gender-unequal destinations would reduce demand for female labor and hence the overall level of female wages in the economy. Taking these adjustments into account, we would find an even larger detrimental effect on female relative wages in exporting firms.

Our paper contributes to the debate on how globalization and, in particular, exporting behavior of firms shapes their wage setting. We document that gender inequality of export partners matters for the gender wage gap among exporting firms. The finding elicits a channel through which gender inequality may spread through internationalization—a channel shown to significantly impact the gender wage gap in exporting firms.

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Appendix A Figures and Tables

Table A1. *Descriptive Statistics: Raw GII*

	Rank	Mean		Rank	Mean
Denmark	1	0.066	Lithuania	26	0.223
Netherlands	2	0.079	Estonia	27	0.250
Switzerland	3	0.080	Latvia	28	0.268
Finland	4	0.082	Hungary	29	0.275
Norway	5	0.088	United States	30	0.276
Belgium	6	0.107	Malaysia	31	0.298
Germany	7	0.115	Russian Federation	32	0.362
Spain	8	0.117	Ukraine	33	0.372
Austria	9	0.131	Chile	34	0.383
France	10	0.137	Argentina	35	0.387
Japan	11	0.138	Romania	36	0.392
Australia	12	0.145	Thailand	37	0.405
Korea, Rep.	13	0.147	Mexico	38	0.425
Canada	14	0.153	South Africa	39	0.457
Italy	15	0.157	United Arab Emirates	40	0.463
Portugal	16	0.168	Brazil	41	0.481
Singapore	17	0.172	Turkey	42	0.490
Israel	18	0.179	Algeria	43	0.525
Ireland	19	0.180	Indonesia	44	0.542
Poland	20	0.183	Iran, Islamic Rep.	45	0.556
Czech Republic	21	0.186	Morocco	46	0.599
Greece	22	0.192	Egypt, Arab Rep.	47	0.607
United Kingdom	23	0.193	Saudi Arabia	48	0.615
Slovak Republic	24	0.202	India	49	0.624
China	25	0.220	Pakistan	50	0.644
Sweden		0.054			
OECD		0.259			
World		0.495			

Notes: The ranking is based on the 50 largest export destination countries for Swedish exporting firms over the 1997–2015 period.

Table A2. *Alternative Specifications: GIWS*

Dep. var: ln(Wage)	(1)	(2)	(3)	(4)	(5)
Female×GIWS	-0.288***	-0.319***	-0.323***	-0.262***	-0.250***
	(0.061)	(0.062)	(0.062)	(0.038)	(0.036)
Female×Export	0.080***	0.090***	0.090***	0.025**	0.019**
	(0.016)	(0.015)	(0.015)	(0.010)	(0.009)
Female	-0.194***	-0.192***	-0.195***		
	(0.040)	(0.042)	(0.043)		
GIWS	0.020	-0.036		-0.062	
	(0.088)	(0.066)		(0.064)	
Export	0.028*	0.001		0.011	
	(0.015)	(0.014)		(0.012)	
ln(Sales)	0.025***	0.013***		0.011***	
	(0.004)	(0.003)		(0.003)	
Female×ln(Sales)	0.003	0.003	0.003	-0.002	-0.002
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Experience	0.017***	0.017***	0.017***	0.008***	0.008***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
Experience^2	-0.029***	-0.028***	-0.028***	-0.030***	-0.030***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Children	0.027***	0.027***	0.027***	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
College	0.254***	0.246***	0.245***		
	(0.006)	(0.006)	(0.006)		
White Collar	0.237***	0.236***	0.237***	0.034***	0.035***
	(0.007)	(0.007)	(0.007)	(0.005)	(0.005)
ln(Firm Size)	-0.012***	-0.016**		0.013***	
	(0.004)	(0.006)		(0.004)	
Functional region FE	yes	yes	yes	yes	no
Industry×Year FE	yes	yes	yes	yes	no
Firm FE	no	yes	no	no	no
Firm×Year FE	no	no	yes	no	yes
Match FE	no	no	no	yes	yes
Adj R^2	0.57	0.59	0.59	0.94	0.94
Observations	4,895,953	4,895,953	4,895,953	4,895,953	4,895,953

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A3. *Standard Errors Clustered at Different Levels*

	Level of Clustering				
	Firm (Baseline)	Individual	Individual×Firm	Firm×Year	Industry (2-digit)
Dep. var: ln(Wage)	(1)	(2)	(3)	(4)	(5)
Female×GIWS	-0.195***	-0.195***	-0.195***	-0.195***	-0.195***
	(0.025)	(0.010)	(0.010)	(0.019)	(0.029)
Match FE	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes
Adj R^2	0.93	0.93	0.93	0.93	0.93
Observations	4,895,953	4,895,953	4,895,953	4,895,953	4,895,953

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. Column (1) corresponds to column (1) in Table 3 with standard errors clustered at the firm level; robust standard errors are in parentheses. Columns (2)-(5) show estimated effects with different levels of clustering of the standard errors, as indicated by the column headings. Additional control variables included in all specifications are Experience, Experience$^2/100$, White Collar, Children, and Female×ln(Sales). Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A4. *Alternative Specifications: GII*

Dep. var: ln(Wage)	(1)	(2)	(3)	(4)	(5)
Female×Export×GII	-0.106	-0.178*	-0.180*	-0.245***	-0.235***
	(0.104)	(0.099)	(0.102)	(0.043)	(0.037)
Female×Export	0.042***	0.050***	0.049***	-0.006	-0.011
	(0.013)	(0.012)	(0.012)	(0.008)	(0.007)
Female×GII	-0.038	-0.023	-0.023	0.003	-0.007
	(0.041)	(0.040)	(0.043)	(0.009)	(0.007)
Export×GII	-0.062	-0.007		-0.039	
	(0.094)	(0.071)		(0.067)	
Female	-0.198***	-0.200***	-0.202***		
	(0.043)	(0.045)	(0.045)		
Export	0.032***	-0.003		0.004	
	(0.010)	(0.010)		(0.008)	
GII	0.047*	-0.013		-0.007	
	(0.027)	(0.014)		(0.009)	
ln(Sales)	0.025***	0.013***		0.011***	
	(0.004)	(0.003)		(0.003)	
Female×ln(Sales)	0.002	0.002	0.002	-0.000	-0.001
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Experience	0.017***	0.017***	0.017***	0.008***	0.008***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
Experience^2	-0.029***	-0.028***	-0.028***	-0.030***	-0.030***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Children	0.027***	0.027***	0.027***	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
College	0.254***	0.246***	0.245***		
	(0.006)	(0.006)	(0.006)		
White Collar	0.237***	0.236***	0.237***	0.034***	0.035***
	(0.007)	(0.007)	(0.007)	(0.005)	(0.005)
ln(Firm Size)	-0.012***	-0.016**		0.013***	
	(0.004)	(0.006)		(0.004)	
Functional region FE	yes	yes	yes	yes	no
Industry×Year FE	yes	yes	yes	yes	no
Firm FE	no	yes	no	no	no
Firm×Year FE	no	no	yes	no	yes
Match FE	no	no	no	yes	yes
Adj R^2	0.53	0.56	0.57	0.93	0.93
Observations	4,895,953	4,895,953	4,895,953	4,895,953	4,895,953

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

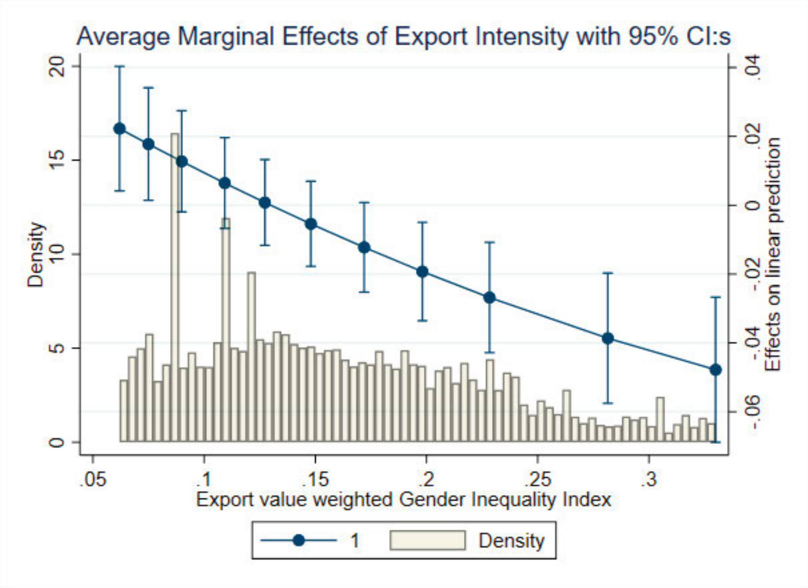

Figure A1. Quadratic GII

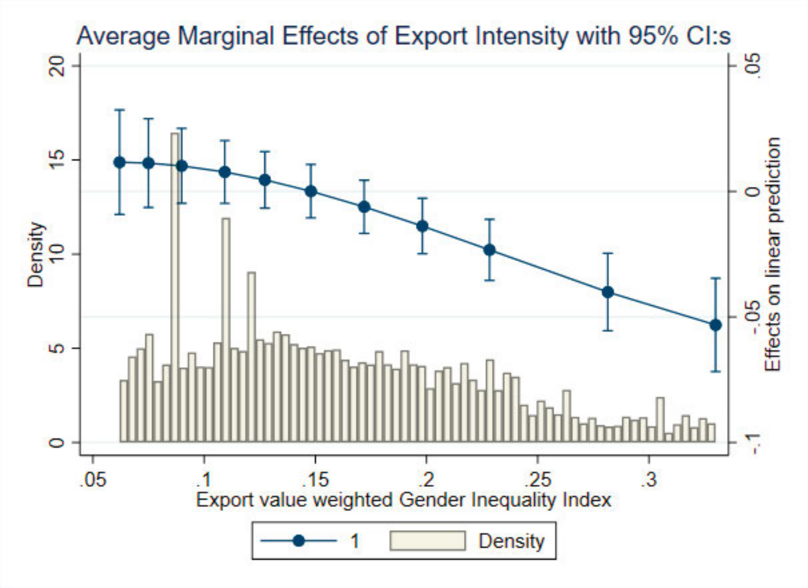

Figure A2. Cubic GII

Table A5. *Standardized GII*

Dep. var: ln(Wage)	(1)	(2)	(3)	(4)
Female×Export×GII(Std)		-0.021***	-0.012***	-0.009***
		(0.003)	(0.002)	(0.002)
Female×Export		-0.011	-0.014	-0.012
		(0.007)	(0.009)	(0.008)
Female×GII(Std)	-0.002***	-0.001	-0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Match FE	yes	yes	yes	
Firm×Year FE	yes	yes		
Firm×Year×Occup. FE			yes	yes
Match×Occup. FE				yes
Adj. R^2	0.93	0.94	0.93	0.95
Observations	4,895,953	4,895,953	4,812,942	4,433,872

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. The GI is standardized. When constructing occupational fixed effects, missing occupations are grouped into one category. Additional control variables included in all specifications are Experience, Experience$^2/100$, White Collar, Children, and Female×ln(Sales). Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

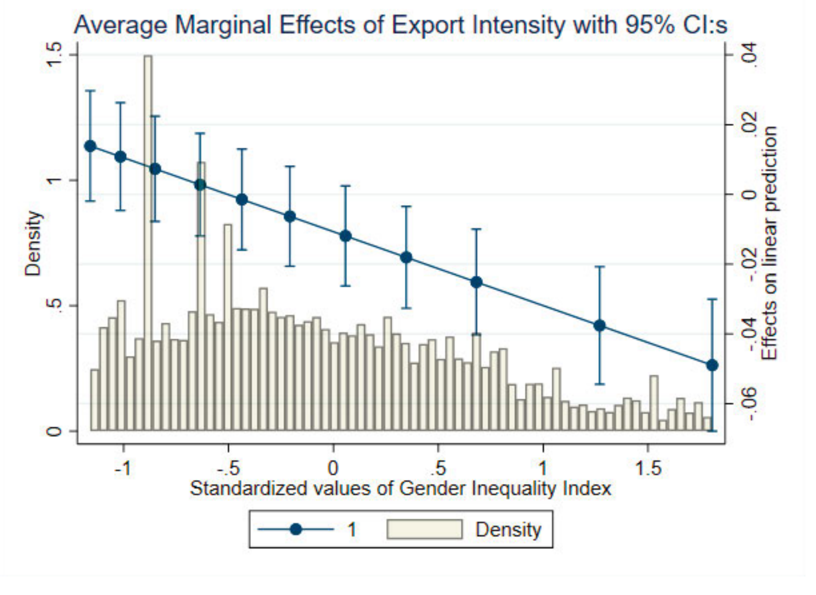

Figure A3. Standardized GII

Table A6. *GIWS and Worker Tenure*

Dep. var: ln(Wage)	Tenure>1 (1)	Tenure>2 (2)	Tenure>3 (3)	Tenure>4 (4)	Tenure>5 (5)
Female×GIWS	-0.254***	-0.264***	-0.294***	-0.293***	-0.300***
	(0.034)	(0.035)	(0.046)	(0.046)	(0.038)
Female×Export	0.020*	0.025*	0.031**	0.031**	0.037***
	(0.011)	(0.014)	(0.015)	(0.015)	(0.013)
Match FE	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes
Adj. R^2	0.94	0.94	0.94	0.95	0.95
Observations	3,764,415	2,969,755	2,363,096	1,888,065	1,522,683

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. The sample is restricted to workers with a certain number of years of tenure, as indicated by the column headings. Additional control variables included in all specifications are Experience, Experience$^2/100$, White Collar, Children, and Female×ln(Sales). Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A7. *GIWS and Firm Ownership*

	MNEs			Local Firms
Dep. var: ln(Wage)	All (1)	Foreign (2)	Domestic (3)	(4)
Female×GIWS	-0.226***	-0.157***	-0.265***	-0.206**
	(0.030)	(0.045)	(0.040)	(0.095)
Female×Export	0.021***	0.018***	0.022*	0.012
	(0.006)	(0.006)	(0.011)	(0.013)
Match FE	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes
Adj R^2	0.93	0.94	0.94	0.93
Observations	7,678,366	4,067,573	3,528,307	1,248,322

Notes: Estimates are based on the worker-level panel data over 1997–2015. The dependent variable is deflated monthly wage in log form. The sample of firms is restricted based on the firm ownership status: columns (1)-(3) display results for multinational exporters, while column (4) presents results for local exporters. Additional control variables included in all specifications are Experience, Experience$^2/100$, White Collar, Children, and Female×ln(Sales). Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A8. *Winsorized and Trimmed GIWS*

	Cutoffs				
	[1,99]	[5,95]	[10,90]	[15,85]	[20,80]
Dep. var: ln(Wage)	(1)	(2)	(3)	(4)	(5)
Panel A. Winsorized					
Female×GIWS	-0.258***	-0.221***	-0.220***	-0.255***	-0.253***
	(0.036)	(0.058)	(0.072)	(0.073)	(0.081)
Adj. R^2	0.93	0.93	0.93	0.93	0.93
Observations	4,895,953	4,895,953	4,895,953	4,895,953	4,895,953
Panel B. Trimmed					
Female×GIWS	-0.258***	-0.254***	-0.301***	-0.327***	-0.297***
	(0.037)	(0.057)	(0.068)	(0.075)	(0.084)
Adj. R^2	0.93	0.93	0.93	0.93	0.92
Observations	4,839,718	4,298,430	3,828,969	3,343,307	2,911,757
Match FE	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated monthly wage in log form. Additional control variables included in all specifications are Experience, Experience$^2/100$, White Collar, Children, and Female×ln(Sales). Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

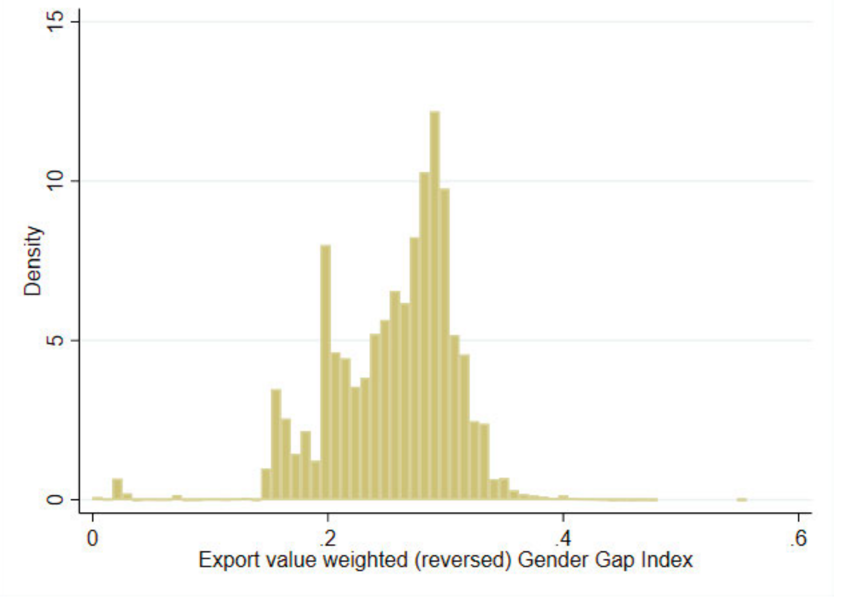

Figure A4. Distribution of the GGI

Essay II. Bargaining for Trade: When Exporting Becomes Detrimental to Female Wages

Co-authored with Daniel Halvarsson, Olga Lark, and Patrik Tingvall

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1 Introduction

A recent report by WTO reveals that trade policies, although designed as gender-neutral, exert a differential impact on men and women. Despite joint attempts across countries at making trade more inclusive, available evidence suggests that globalization might, in certain circumstances, worsen female opportunities in the labor market (The World Bank, 2020). This illustrates a concerning gap between intended policies and the actual outcomes, and the fact that globalization and its effect on gender inequality are yet not fully understood.

In this paper, we study how exports, and the associated need for communication with foreign partners, shape the gender wage gap. The emerging literature on the topic has highlighted two personal attributes that are deemed important for exports and hence might explain the asymmetric remuneration of men and women in globalized firms. The first one is flexibility in working hours, which is needed when operating across different time zones. If women are less time-flexible or perceived as such, they may face a relative wage penalty in exporting firms (Bøler et al., 2018). Another personal attribute relates to gender differences in interpersonal skills, which are arguably important for communication with foreign partners. Since women are found to have a comparative advantage in such skills, exporters could, on the contrary, generate better opportunities for female workers, especially so in white-collar occupations (Bonfiglioli and De Pace, 2021).[1]

Notably, earlier lines of research have also documented the male comparative advantage in negotiations—a valuable social skill when dealing with a diversity of cultures and social norms, intrinsic to foreign partners around the world.[2] Hence, the question of which type of gender-specific skills is most needed and rewarded by exporters remains open. We add to the literature by documenting how the type of exported goods shapes firms' demand for particular skills and thereby drives a disproportionate wage impact across genders. Dealing with foreign contractors across the globe requires a certain degree of bargaining and relationship building. If intensified exports increase firms' demand for bargaining skills, this could offset the positive effect of the female comparative advantage in interpersonal skills and trigger women a wage penalty.

Our main finding is that when goods export intensifies, the gender wage gap widens and does more so for firms in high contract-intensive industries, where buyer–seller interaction is necessary for trade to occur. This result emphasizes the role of male comparative advantage in bargaining when serving

[1] For the related literature on the female comparative advantage in interpersonal skills see Spitz-Oener (2006), Black and Spitz-Oener (2010), Borghans et al. (2014), Ngai and Petrongolo (2017), and Cortes et al. (2021), among others.

[2] See e.g. Walters et al. (1998), Stuhlmacher and Walters (1999), Kray and Thompson (2004), and Hederos Eriksson and Sandberg (2012) on the evidence of male comparative advantage in bargaining.

foreign markets, and the importance of bargaining skills for the remuneration of workers. To further underline the connection between exports and demand for negotiation skills, we show that the observed negative effect is primarily driven by white-collar workers, and in particular, by managers and sales workers. Based on our findings, we conclude that doing business with a variety of partners across the globe alters the job skill demands of exporters.[3]

An additional contribution we make is to separate the effect of foreign ownership from the effect of exporting—the two distinct but related aspects of firm globalization. As suggested by recent literature (Kodama et al., 2018; Tang and Zhang, 2021; Halvarsson et al., 2022), multinational enterprises (MNE) are able to transfer their corporate culture across international borders and thereby affect gender-specific labor market outcomes in the subsidiaries in the host countries. Moreover, Lanz and Miroudot (2011) document that the share of intra-firm export to total export in the Swedish manufacturing sector is substantial (ca 51 percent), implying that product contractability and negotiations are of less relevance for trade among a handful of Swedish (multinational) firms. To account for the differential impact of foreign ownership and to avoid contamination of the effect of exporting, we exclude foreign-owned firms from the main sample and split the effect of interest into that exerted by foreign-owned versus domestic exporters.

In high contract-intensive industries, we find that the negative impact of exports on the gender wage differential becomes less pronounced when foreign subsidiaries are included in the sample. A closer look at the two types of firms reveals that exports undertaken by domestic firms exert a relatively strong impact on the gender wage gap, as compared to exports by foreign-owned firms, which do not appear to exert any significant effect. In a similar vein, we also find that domestic sales of high contract-intensive goods do not impact the gender wage gap, further connecting our findings to exporting activities. Our results are robust to a series of specification tests, including tests of the aforementioned flexibility hypothesis. Specifically, the lack of temporal flexibility by female workers does not appear to drive our estimates for export intensity and contract intensity. Lastly, the rent-sharing analysis indicates that the male ability to negotiate gets rewarded when there are rents to compete for, and that is in high contract-intensive industries. Taken together, our findings highlight a novel and important interplay between firms' demand for interpersonal and bargaining skills, the type of goods they export, and gender inequality.

The rest of the paper unfolds as follows. The next section discusses the related literature, followed by a section where we outline the main empirical

[3]In support, we demonstrate, via occupational structure analysis, that exports of contract-intensive goods shift the employment composition in the respective firms, making a larger fraction of the labor force engaged in selling and bargaining activities. The occupational task-content literature was spurred by D. H. Autor et al. (2003) and developed further in Acemoglu and D. Autor (2011), who propose a task-based framework building on D. H. Autor et al. (2003), Acemoglu and Zilibotti (2001), and Costinot and Vogel (2010), among others.

strategy and the empirical challenges we face. The fourth section describes the data, sample, and measurements used in the empirical analysis. Results, robustness checks, and discussion of potential mechanisms come in section 5, while section 6 concludes the study and provides some suggestions for future research.

2 Related Literature

In a broad sense, our study connects to a vast body of work on gender inequality in the labor market (Altonji and Blank, 1999; Blau and Kahn, 2000; Goldin, 2014). This literature highlights a number of factors that are considered important for explaining the gender gap in earnings, such as differences in human capital, occupational and industry segregation, temporal flexibility, as well as discrimination. Olivetti and Petrongolo (2016), Card et al. (2016), and Blau and Kahn (2017) constitute the more recent contributions in the field, where the focus has shifted towards the differences in psychological attributes and bargaining power across genders as potential explanations for the observed gender gaps.

Our study also relates to experimental and behavioral studies that point out three important differences in preferences and attitudes across genders. First, extensive literature reviews by Croson and Gneezy (2009) and Eckel and Grossman (2002) document that women are consistently more risk-averse compared to men. Added to that, men also show a higher willingness to lead, irrespectively of the gender composition of the team (Born et al., 2022). Second, women are also found to be reluctant to engage in competitive interactions and bargaining, and their performance and participation decrease compared to that of men, when competitive pressure increases (Gneezy et al., 2003; Bowles et al., 2005; Niederle and Vesterlund, 2007; Niederle and Vesterlund, 2011; Hederos Eriksson and Sandberg, 2012). The conclusions with respect to gender differences in competitiveness, however, remain context-specific and generally less univocal (Bertrand, 2011). Finally, by initially claiming a lower surplus, women appear to be less assertive in negotiations and as a consequence benefit less, in the end, (Kray et al., 2001; Kray and Thompson, 2004). Altogether, this strand of literature suggests that men are better negotiators and appear to be superior to women in more risky and competitive environments. Relatedly, our paper also connects to studies on the importance of face-to-face communication between partners (Bernard et al., 2019; Battiston et al., 2020; Söderlund, 2020; Startz, 2021).

Although we relate to diverse strands of the literature, we speak primarily to the debate on the role of globalization in shaping gender wage inequality.[4] In this regard, Juhn et al. (2014) exploit tariff reductions as an exoge-

[4] Related to our question, Helpman (2018) provides a recent and extensive review of the literature on globalization and inequality in general.

nous shock and analyze the effect on the gender-specific outcomes in Mexican firms. Their findings show that, by virtue of technological upgrading, trade liberalization improves labor market outcomes for female workers involved in blue-collar, but not white-collar tasks. Bonfiglioli and De Pace (2021) provide more recent evidence on the nexus between trade, female labor, and tasks and find no average effect of export intensity on the relative female wages in Germany. However, when the sample is split by occupation, the authors detect a reduction (an increase) in the gender wage gap for white-collar (blue-collar) workers as export surges. They argue that the mechanism behind their findings relates to the female comparative advantage in interpersonal skills needed to serve foreign markets. On the other hand, Bøler et al. (2018) who rely on matched employer–employee data from Norway, find that export increases the wage differential between college-educated men and women. A suggested explanation for this result is that female workers lack flexibility in working hours (Goldin, 2014), which is argued to be particularly important for firms trading across different time zones.

Taken together, the existing literature closest to our study has investigated two potential mechanisms through which exporting might affect gender-specific labor outcomes: firms' temporal flexibility requirement and the role of female advantage in interpersonal skills. We contribute to the discussion with the finding that firms, involved in international commerce of high contract-intensive goods, exhibit a larger gender wage gap. Our findings align with the theory suggesting that females are relatively disadvantaged in negotiations—a phenomenon underlined by experimental and behavioral studies. Hence, while changing the set of job tasks necessary for a firm to serve a foreign market, exporting tends to widen the gender wage gap by reinforcing male comparative advantage in bargaining. These findings increase our knowledge of firms' demand for gender-specific human capital and allow us to better understand the role of globalization in affecting gender wage inequality.

3 Empirical Strategy

To study the nexus between exporting and wage inequality on the one hand, and the role of contract intensity, on the other hand, we rely on an empirical wage equation that includes a three-way interaction term of a female dummy, firm export intensity (defined as total goods export through total sales), and the measure of a firm's contract intensity by industry. Formally, the wage of person i, employed at firm j in industry k at time t, can be written as follows:

$$\begin{aligned} ln(Wage)_{ijkt} = & \beta_1[Female_i \times (Export/Sales)_{jt} \times CI_k] \\ & + \beta_2[Female_i \times (Export/Sales)_{jt}] \\ & + \mathbf{X}_{it}\gamma + \mathbf{F}_{jt}\phi + \eta_{ij} + \eta_{jt} + \varepsilon_{ijkt} \end{aligned} \tag{1}$$

where $\mathbf{X}_{it}$ and $\mathbf{F}_{jt}$ are the two vectors, capturing worker and firm control variables[5], while η_{ij} and η_{jt} denote employer–employee match fixed effects and firm–year fixed effects, respectively—the two central parts of our identification strategy.[6]

Firstly, worker and firm fixed effects, which are embedded in match fixed effects, remove omitted variable biases associated with individual and firm characteristics that are constant over time, such as individual worker ability or wage-setting practices of a particular firm. They also control for match differences between individuals that may arise due to worker labor market sorting. If, for example, exporting firms have a higher propensity of recruiting individuals with certain characteristics (including gender), or alternatively if certain individuals seek to work for exporting firms, estimates of the gender wage gap will be biased. In a similar vein, if poorly matched workers exit firms first, when a negative shock hits the firm, it would also bias the estimated effects of interest. When making the inference, within-match identification allows us to exploit a finer source of variation stemming from workers' wages and firms' export activity, while holding the within-firm gender composition constant. Moreover, match fixed effects reduce concerns associated with possible reverse causality since an individual worker is unlikely to exert a sizable effect on a firm's export decisions.

Secondly, the interaction of firm and year fixed effects accounts for both aggregate confounders (through year dummies) and for firm-specific unobserved time-varying heterogeneity. The latter might, for example, encompass concurrent changes to firm-specific labor demand and/or changes to its workforce composition. Most importantly, firm-level productivity shocks, which might simultaneously affect both the exporting behavior of firms and workers' wages and therefore make exports endogenous, are captured by firm–year fixed effects. In the most stringent specification, we also augment model (1) with firm–occupation–year fixed effects to control for contemporaneous shocks to firm productivity that might differently affect occupations and lead to changes in firm occupational composition, as well as individual–firm–occupation fixed effects to ensure the effects we find are not driven by workers switching occupation during the period of study. We use these, even more granular, occupational fixed effects as a robustness check of our main findings rather than the main specification. The reason is that switching an occupation might be

[5]For individual workers, the model controls for the potential labor market experience (*Experience*) and its square (*Experience*^{2}), the dummy variable for having children in household under 18 years old (*Children*), a dummy variable for college education (*College*), and a dummy variable for a white-collar occupation (*White collar*). As for the firm level controls, we use (log) sales interacted with the female dummy (*Female*$\times$*ln(Sales)*).

[6]In Table A2 in the Appendix, we present several versions of model (1) with different levels of fixed effects. Table A2 also shows the estimates of all control variables that are included in all specifications.

an outcome of its own and therefore restricting workers to stay in the same occupation might introduce a selection effect to our estimation.

Taken together, our identification strategy thus relies on the assumption that, after controlling for match fixed effects, observable worker and firm characteristics, and unobservable time-varying firm characteristics, firm export decisions are orthogonal to other shocks that may impact workers' wages trajectories. The empirical approach applied in this paper is reminiscent of earlier studies on globalization and gender wage inequality, in particular, Bøler et al. (2018) and Bonfiglioli and De Pace (2021). The extensive number of fixed effects included in the model prevents us from using standard transformations to handle fixed effects in panel data estimation. With high-dimensional fixed effects as in model (1), particular algorithms must be used to handle the dimensionality problem and we rely on the algorithm by Correia (2016), allowing us to include multiple levels of fixed effects. The standard errors are clustered at the firm level in all specifications.

4 Data, Sample, and Measurements

4.1 Data

When analyzing the connection between contract intensity, exports, and the gender wage gap, we use matched employer–employee data provided by Statistics Sweden. The data span the period from 1997 to 2015 and offer detailed information on both individuals and firms, as well as customs data for exporting firms.

The main source of information on individual wages is the annual labor force survey, the Wage Structure Statistics (WSS), conducted by the Swedish National Mediation Office (*Medlingsinstitutet*). The survey provides full-time equivalent monthly earnings and contracted work hours, which are comparable to hourly wage rates. The survey data are available for all public sector employees with positive hours worked in the survey month (usually September). For the private sector, the survey covers all workers in firms with at least 500 employees and at least 50 percent of the remaining workforce. Specifically, private firms included in the structural business statistics (FEK) form the sampling units of the survey, which are stratified according to industry affiliation and firm size. Since we are specifically interested in the effect of exporting, public-sector firms are excluded from the analysis. As a result, our sample includes approximately 50 percent of all private-sector workers (approximately two million individual workers) in any given year. Due to the stratification of smaller private-sector employers in WSS, there exist gaps for the dependent variable in some years. While it is possible to impute individual wages for the missing years, we have opted not to do so due to the possibility of individuals being temporarily employed elsewhere.

To the above-mentioned sample, we have merged a number of data sets: (i) the longitudinal integrated database for health insurance and labor market studies (LISA), covering all individuals in the labor force and their detailed socio-demographic characteristics; (ii) the FEK dataset, containing information on profits, sales, value-added, and industry affiliation for all private non-financial companies; (iii) the labor statistics based on administrative sources (RAMS), providing information on the location and the number of employees across all plants in Sweden, whereas the plant data are aggregated to the firm level; and, finally, (iv) the Swedish Foreign Trade Statistics covering Sweden's export of goods broken down by country of destination and type of goods classification.[7] Table A1 in the Appendix contains detailed descriptions of all variables included in the analysis together with information on the data sources.

In the merged data set, all employed individuals are linked using a unique identifier to the firm, where they have earned their highest yearly income. As mentioned previously, we only consider domestic exporters for the main sample. We further restrict the sample by excluding all part-time workers to avoid biases associated with part-time penalties (Manning and Petrongolo, 2008; Albrecht et al., 2018), and also individuals below 18 and above 67 years of age. In the final data set used for the analysis, we have at our disposal a sample of 4,886,752 worker–firm–year observations, represented by 5,166 private sector exporting firms.

4.2 Measures of Contract Intensity

Measuring the demand for interpersonal and bargaining skills across industries poses a considerable empirical challenge. We meet this challenge by exploiting the CI index developed by Nunn (2007), higher values of which indicate industries that rely more heavily on differentiated, or relationship-specific, input goods.[8] Building on the Rauch (1999) commodity classification, Nunn (2007) constructs a measure that quantifies the relationship specificity of intermediate inputs used in the production of a particular final good. He argues that industries, heavily relying on differentiated intermediate inputs, are characterized by a higher degree of interpersonal contact, needed between a buyer and a seller to complete a deal. Such industries are called contract-intensive. Nunn (2007) creates a ranking of industries based on the measure, with greater

[7] Due to compulsory registration at Swedish Customs, the data cover all transactions in goods with countries outside the EU (Extrastat). Trade data for EU countries have been collected via a total population survey subject to a threshold, implying that the smallest transactions are excluded from the consideration. In addition to the submitted values, Statistics Sweden complements the data using information from VAT declarations to the Swedish Tax Agency.

[8] The CI index has been extensively used in the literature to answer a variety of research questions. See e.g. Altomonte and Békés (2009), Casaburi and Gattai (2009), Ferguson and Formai (2013), Bartel et al. (2005), Söderlund and P. G. Tingvall (2014), and Strieborny and Kukenova (2016), among others.

values of the CI index indicating more contract-intensive industries. According to the theoretical framework behind the measure, contract intensity is an exogenous industry characteristic since it stems from the peculiarities of a production process and the importance of certain relationship-specific inputs therein. In a seminal paper, Nunn (2007) demonstrates that countries, characterized by well-developed institutions, exhibit a comparative advantage and specialize in goods intensive in buyer–seller interactions, ultimately leading to a higher volume of trade in contract-intensive goods in such countries.

In this paper, the CI index is matched to firms based on the Swedish industry classification SNI2007 (equivalent to NACE Rev.2) at the 4-digit level. To take care of the firms changing industry classification during the years 1997–2015, we assign a firm to the same industry throughout the sample period. Examples of the 4-digit SNI2007 industries with a high CI index include the manufacturing of computers, graphical services before print, and breweries. In contrast, low CI index industries are, for instance, the production of malt, the production of meat, and the manufacturing of electrical cables.

In addition to the CI index used for our main analysis, we construct two alternative measures of firm contract intensity: the SPIN CI index and the Export CI index.[9] The SPIN CI index is obtained by matching the original CI index to firms based on the SPIN2007 product classification instead of SNI2007. Specifically, the SPIN2007 product classification in our data refers to the firm's main export product, as opposed to the SNI2007 industry classification, which refers to the firm's main (self-reported) economic activity at large. As for the Export CI index, it reflects the ratio of all exported differentiated goods to the total firm–year export value. To make this measure exogenous with respect to current firm operations, we obtain an average Export CI index over the first three years since 1997 (or since the first year of export) and use this value for all subsequent years when we observe the firm. The first three exporting years are thus treated as pre-sample observations and are excluded from the subsequent analysis. The two alternative measures of contact intensity are firm-specific and are constructed in order to focus on the firm's export activity, rather than its domestic operations when evaluating the importance of contract intensity for female labor market outcomes.

4.3 Descriptive Statistics

In Table 1, we group firms based on industry-level contract intensity and display sample means and medians for a series of firm-level variables. We define a firm as high (low) contract-intensive if it operates in an industry that lies

[9]SPIN2007 is an acronym for Standard for Swedish product classification by industry. The consistent SPIN2007 product classification is available from 2000 onward.

above (below) the median CI index value in the firm-level sample.[10] Notably, the mean female share of the labor force of 28 percent is identical for high and low contract-intensive firms, suggesting that both types of firms exhibit similar gender workforce composition. Firms with high CI index employ a larger number of employees on average and their mean sales are somewhat higher compared to their low CI counterparts. Also, the mean export intensity is 23 percent for high contract-intensive firms and only 18 percent for low contract-intensive firms, suggesting that the latter engage less in international as opposed to domestic trade. Notably, when comparing the export activity of the two types of firms across the median, they appear identical in that dimension. In sum, the division of exporting firms according to the Nunn (2007) CI index does indicate some differences in the observable firm-level characteristics but they do not appear to be substantial across the two subsamples. To highlight possible differences in the type of workforce employed in these firms, we proceed by analyzing the individual attributes of the workers.

Table 1. *Firm Descriptive Statistics: High Versus Low CI Index Firms*

	Means		Medians	
	High CI	Low CI	High CI	Low CI
Firm size (number of employees)	294	237	64	59
Sales (mln €)	8,498	6,809	975	959
Export/Sales	0.23	0.18	0.06	0.06
CI index	0.64	0.37	0.64	0.40
Female share of labor force	0.28	0.28	0.23	0.24
Number of firms	2,619	2,547	2,619	2,547

Notes: All numbers are based on the panel of firm-level data of domestic exporting firms for 1997–2015. Firms are classified as high (low) contract-intensive if their CI index is above (below) the median CI index in the sample.

Table 2 displays individual characteristics of an average female and male worker in high and low CI index firms. According to the observable characteristics of the workforce, high contract-intensive firms appear fairly similar to their low contract-intensive counterparts. Specifically, while the two types of firms hire workers of similar age and having similar labor market experience, the share of workers with children remains 3 percentage points higher in firms more dependent on tight buyer–seller interaction. Another notable feature of firms in high contract-intensive industries is that they exhibit a higher degree of skill intensity by way of employing more college-educated and white-collar workers. Finally, while high CI index firms pay slightly higher wages on av-

[10]We follow a similar categorization of firms by contract intensity in all subsequent parts of the paper.

erage, the ratio of female to male wages is 0.91, which is the same for the two types of firms.

Table 2. *Individual Descriptive Statistics: High Versus Low CI Index Firms*

	High CI			Low CI		
	All	Female	Male	All	Female	Male
Monthly Wage (€)	3,476.29	3,237.51	3,541.95	3,041.08	2,837.12	3,112.33
Monthly Wage (log)	8.09	8.02	8.11	7.97	7.91	7.99
Experience	20.49	19.09	20.87	21.79	20.53	22.22
Age	42.11	41.42	42.30	42.10	41.71	42.23
Share with children	0.44	0.43	0.44	0.41	0.41	0.41
Education						
Share with college education	0.22	0.26	0.20	0.10	0.15	0.08
Occupation						
Share of white-collar workers	0.59	0.74	0.55	0.39	0.53	0.34
Share of blue-collar workers	0.41	0.26	0.45	0.61	0.47	0.66
Number of individuals	490,255	119,406	370,849	365,413	105,604	259,809
Number of individual–year obs	2,886,829	622,617	2,264,212	1,999,923	517,799	1,482,124

Notes: All numbers refer to average values of the indicated variables for the panel of worker-level data for 1997–2015. Workers belong to high (low) contract-intensive industry if the CI index of their employer is above (below) the median CI index in the sample.

Taken together, the summary statistics in Tables 1 and 2 indicate some differences between high and low contract-intensive firms, but the average characteristics of their male and female workers still remain comparable, with the exception of skill intensity. Importantly, both types of firms display similar gender workforce composition. Our empirical strategy, outlined in detail in the previous section, controls for the potential biases that average differences presented above may bring to the estimated effects of interest.[11]

5 Results

5.1 Contract Intensity, Goods Exports, and the Gender Wage Gap

Before delving into the main results with contract intensity, we first examine the impact of firms' export intensity on the relative female wages in general. To this end, we estimate model (1) with employer–employee match fixed effects and firm–year fixed effects, and an interaction term of the female dummy and export intensity. In column (1) in Table 3, we document an estimate of -0.029 for Female×(Export/Sales), which is statistically significant at the 5 percent level. That is, in the extreme case of export intensity going from zero to one, the relative wage of female workers decreases by 2.9 percent on average.[12] We can also interpret the result through the lens of a one standard

[11] See Table A3 for a summary of the average wages across educational specializations.

[12] See Table A4 in the Appendix for the effect of export intensity on the gender wage gap using versions of model (1) with different sets of fixed effects. Notably, the estimate of

deviation increase in export intensity, which would yield approximately a 1 percent decrease in the relative female wages.[13] Our initial finding suggests that changes in firm export activity appear to exert a negative impact on female workers' wages in the respective firms.

Table 3. *Export, contract intensity, and the gender wage gap*

Dep. var: ln(Wage)	(1)	(2)	(3)	(4)
Female×(Export/Sales)×CI		-0.118***	-0.109***	-0.093***
		(0.037)	(0.026)	(0.019)
Female×(Export/Sales)	-0.029**	-0.016**	-0.011***	-0.009**
	(0.014)	(0.007)	(0.004)	(0.004)
Match FE	yes	yes	yes	no
Firm×Year FE	yes	yes	no	no
Firm×Year×Occup. FE	no	no	yes	yes
Match×Occup. FE	no	no	no	yes
Observations	4,886,752	4,886,752	4,306,607	4,048,976
Adj R^2	0.930	0.930	0.937	0.943

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. Additional control variables included in all specifications are Experience, Experience$^2/100$, Children, College, White collar, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Column (2) in Table 3 shows the key result of estimating model (1) with the triple interaction between the female dummy, firm export intensity, and the CI index. As before, we find a negative association between goods export and relative female wages. In particular, the gender wage gap widens as export intensity goes up, and it does more so in high contract-intensive industries. At the mean level of the CI index (0.54), we find a negative estimate of -0.016 for the Female×(Export/Sales) interaction.[14] If export intensity increases by one standard deviation the relative female wages would, on average, decrease by 0.5 percent in firms with a mean level of contract intensity. As for the interaction Female×(Export/Sales)×CI, the negative estimate of -0.118 implies that the gender wage gap widens more when firm contract intensity is high.

To ensure that the effects in column (2) are not driven by shocks to particular occupations, we augment model (1) with Firm×Year×Occupation fixed effects.[15] As seen in column (3) in Table 3, the extended fixed effects do not alter the main conclusions but make the estimates slightly less negative. Notably, the results are robust to the inclusion of both sets of occupational

Female×Export switches from a positive to a negative sign when match fixed effects are included in the model—a finding discovered earlier and explained in detail by Bøler et al. (2018).

[13] The standard deviation of export intensity in the sample is 0.31.

[14] In all specifications, we choose to use a demeaned version of the CI index for its easier interpretation.

[15] Occupations are defined according to the Swedish Standard Classification of Occupations (SSYK96) at a detailed three-digit level.

fixed effects in the same specification, as in column (4). Results in columns (3) and (4) indicate that neither shocks to particular occupations, nor employees switching an occupation within the firm due to increased exports appear to drive our main findings. When comparing the obtained estimates in Table 3, we observe a persistent and negative sign throughout, as well as estimates similar in sign, magnitude, and precision. We interpret the stability of our findings as conclusive evidence that increased export intensity yields, on average, a larger gender wage gap, whereas the effect appears to be consistently stronger for firms in high contract-intensive industries.

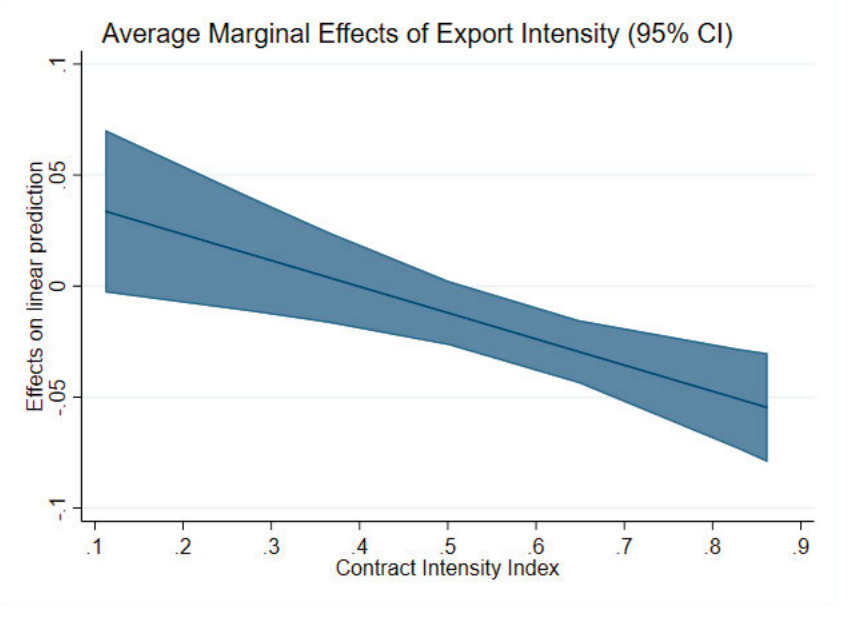

Figure 1. Marginal effects of goods export intensity

Figure 1 corresponds to the estimates in column (2) in Table 3 and allows for an easy and intuitive interpretation of our main finding. It shows the average marginal effects of goods export intensity on relative female wages (y-axis) across different levels of the CI index (x-axis). The linear prediction is surrounded by 95 percent confidence bounds, whereas the estimates are statistically significant at the 5 percent level as long as the confidence bounds do not intersect the zero horizontal line. As expected, we observe in Table 3 and in Figure 1 an identical estimate of Female$\times$(Export/Sales), at the mean value of the CI index. The figure also clearly illustrates a negative slope of the triple interaction term, indicating that the effect of increased export intensity on the gender wage gap becomes more negative with higher values of the CI index. When the CI index is below the sample mean, the estimated effects are not statistically significant. Considering the magnitude of the estimate for the most contract-intensive firms, that is for firms with a CI index above 0.85, we observe a coefficient of approximately -0.05. In these firms, the gender wage gap would widen by 1.6 percent as a result of a one standard deviation increase in export intensity—a non-negligible effect that highlights the economic importance of our findings. Figure 1 provides visual evidence that exports in high contract-intensive industries yield adverse impacts on female labor market outcomes and induce a wider gender wage gap.

5.2 Robustness

Robustness of main results

To validate our main findings, we apply a series of modifications to the baseline model. The results of the analysis are presented in Table 4, where the restrictions are indicated by the column heading. Due to data noisiness for smaller firms and following the convention in the literature, we exclude firms with less than 50 employees in column (1).[16] Another potential concern relates to recently hired employees, who might be differently affected by increased export intensity compared to their tenured colleagues. To address this issue, we exclude all workers with less than three years of tenure in column (2). The estimates for the two interaction terms, Female×(Export/Sales)×CI and Female×(Export/Sales), hardly change when we consider firms with more than 50 employees, whereas both estimates become slightly more negative when we restrict our focus to tenured workers. Hence, the sign and the size of the main interaction effects found in column (2) in Table 3 survive both of these restrictions.

Table 4. *Robustness I*

Dep. var: ln(Wage)	$>$ 50 employees (1)	3+ yrs tenure (2)	Manufacturing (3)	Incl. fgn-owned (4)	Only fgn-owned (5)
Female×Export/Sales×CI	-0.119***	-0.123***	-0.110***	-0.082**	-0.001
	(0.039)	(0.040)	(0.042)	(0.036)	(0.025)
Female×Export/Sales	-0.016**	-0.015*	-0.021**	-0.013**	-0.002
	(0.008)	(0.008)	(0.008)	(0.005)	(0.005)
Match FE	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes
Observations	4,627,318	2,968,108	2,575,261	9,094,119	4,055,687
Adj R^2	0.929	0.939	0.939	0.932	0.938

Notes: Estimates are based on the worker-level panel data over 1997–2015. Workers of the following exporting firms are considered: (i) domestic in columns (1)–(3), (ii) all in column (4), (iii) only foreign-owned in column (5). Additional control variables included in all specifications are Experience, Experience^2/100, Children, College, White collar, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

[16] The potential source of errors with smaller firms stems from changes in firm identifiers in the event of a merger or an acquisition. To circumvent this problem, Statistics Sweden has created FAD-identification numbers that hold a firm ID constant as long as the majority of its employees are present for two consecutive years. The method becomes less reliable when the total number of employees is small, hence the increased risk of errors and possible inconsistencies in firm identifiers of small firms.

So far, we have included all sectors of the economy in the analysis. It is however common in the international trade literature in general, and in the recent papers on globalization and the gender wage gap in particular (e.g. Bøler et al. (2018)), to consider only the manufacturing sector, where most of the exporting activity occurs. When focusing on manufacturing firms, we detect negligible changes to the estimates, compared to the benchmark estimates in Table 3. Next, when we add foreign-owned firms to the sample in column (4), our main finding still holds—increased export intensity negatively affects female workers and more so in high contract-intensive industries. The estimated effects are now smaller in absolute value and less significant, which can possibly be explained by intra-firm trade that foreign-owned exporters are involved in. Notably, in column (5) when we only consider foreign-owned exporters, neither of the estimates remains significant. This result alludes to the fact that firm contract intensity does not play a role in intra-firm trade. Namely, being part of a larger multinational corporation allows such firms to bypass contracting problems since a lot of their operations occur within the corporation.

We proceed by examining whether our main results are robust to the measurement of contract intensity and firm assignment into industries. In the main part of the analysis, we use the Nunn (2007) CI index to measure firm contract intensity, which we merge with other variables based on firm industry affiliation (SNI2007 classification). As a first robustness check, we rely on the same CI index but we match it to firm-level data using a different industry classification. Specifically, we reassign all firms to an industry based on their main exported product (SPIN2007 product classification). The results from the new SPIN industry mapping are shown in column (1) in Table 5. Although we now connect firm contract intensity to its export operations more directly, we find quite similar estimates. For example, the estimate of the interaction term Female$\times$(Export/Sales)$\times$CI using SPIN industry matching is -0.086, compared to -0.118 using the standard SNI2007 industry mapping. The results indicate that our main finding appears to be robust to the alternative definition of firm industry affiliation.

Next, we construct a firm-specific measure of contract intensity, Export CI, which reflects the fraction of differentiated exported goods at the firm–year level. We obtain the new measure by matching firm export products from the customs data to the Rauch (1999) classification of products. Under our definition, the fraction of differentiated exported goods is determined by the firm export value of all differentiated products over the total export value in each year. The new measure of contract intensity confirms the negative association between exports and relative female wages found previously, as seen in column (2) in Table 5. Evaluated at the mean level of the Export CI index, we obtain a larger estimate in absolute value (-0.026), compared to our baseline estimate of -0.016 in column (2) in Table 3. In column (3), we make the Export CI index exogenous to current firm operations by using a predetermined share of differentiated export goods, which is then fixed across the subsequent years.

Although the exogenous measure yields less variation and fewer observations due to the exclusion of the pre-sample years, we find reassuringly similar estimates in column (3) and column (2), when the Export CI index varies over time.

Table 5. *Robustness II*

	(1) CI SPIN	(2) Export CI time-varying	(3) Export CI time-invariant	(4) PPML	(5) Dom. sales
Female×Export/Sales×CI	-0.086**	-0.045***	-0.061***	-0.139***	-0.125***
	(0.035)	(0.017)	(0.022)	(0.043)	(0.043)
Female×Export/Sales	-0.019**	-0.026**	-0.028**	-0.019**	-0.017**
	(0.008)	(0.012)	(0.012)	(0.008)	(0.008)
Female×Dom.Sales×CI					-0.007
					(0.012)
Female×Dom.Sales					-0.001
					(0.002)
Match FE	yes	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes	yes
Observations	4,065,202	4,814,550	3,608,677	4,886,752	4,886,752
Adj. R^2 / Psuedo R^2	0.936	0.930	0.937	0.934	0.930

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. The dependent variable is deflated and annualized wage in log form in columns (1), (2), (3), and (5) and in levels in column (4). In column (2), the Export CI index is allowed to change over time; in column (3), the Export CI index is fixed to its value in the estimation pre-period and is not varying over time. Additional control variables included in all specifications are Experience, Experience$^2/100$, Children, College, White collar, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

To test for the sensitivity of results with respect to the choice of estimator, we in column (4) employ a Pseudo Poisson Maximum Likelihood (PPML) estimation method, which allows dispensing with the log-linear form of equation (1). The results correspond to the same specification as before but the wages are now estimated in levels. According to our findings, the main conclusion continues to hold irrespective of the functional form of the empirical wage equation we use.

A potential concern to raise would be that the effects we find for firm contract intensity are not driven by its international operations and sales abroad, but rather its sales in general, be it domestic or foreign. We have partly already addressed this issue since we have factored in domestic sales in our measure of export intensity (Export/Sales). To make an additional check, we augment the baseline specification with the female dummy interacted with domestic sales, and a triple interaction Female×Domestic sales×CI. According to column (5) in Table 5, neither domestic sales nor domestic sales interacted with the CI index exert any statistically significant effect on the gender wage gap.

Hence, the inclusion of domestic sales as a separate control does not appear to affect our findings and further strengthens our claim that it is specifically globalization and exports that appear to decrease relative female wages in highly contract-intensive firms.

5.3 Heterogeneity Analysis

Our key finding that the gender wage gap widens when firms in high contract-intensive industries are exposed to intensified export is robust to alternative measures of contract intensity and pertains to international, rather than domestic, trade. The effect we identify might not, however, be homogeneous across different groups of workers. If we consider bargaining with partners in other countries, for example, it seems likely that the tasks associated with it are carried out by workers in particular occupations and/or with particular educational backgrounds. To explore the heterogeneous effects of increased exports across employee subgroups, we divide all workers into subsamples with respect to their educational attainment and observed occupational category.

In the first two columns in Table 6, the sample is split based on workers' highest attained educational level. In columns (1) and (2), we observe that the estimates for workers with and without college education almost mirror each other and also align with the previous estimates in column (2) in Table 3 for all employees. In a firm with an average level of contract intensity, the wage of a college-educated woman appears to decrease by 0.6 percent relative to the wage of a college-educated man, once export intensity increases by one standard deviation. Hence, the negative association between exports and relative female wages, which is increasingly negative in contract intensity, appears to hold for all workers, irrespective of their educational level.

Next, we run the baseline specification separately for white-collar and blue-collar workers in columns (3) and (4), respectively. Despite a close similarity in sample size across the two subgroups, with around 2.4 million observations each, we only find statistically significant effects for white-collar workers. The result implies that the widening of the gender wage gap due to increased export exposure is concentrated among workers performing white-collar tasks, with no notable impact on their colleagues in blue-collar tasks. Focusing on the white-collar workers and holding contract intensity at the mean, the estimated effect of a one standard deviation increase in export intensity on the relative female wages amounts to approximately -0.5 percent. Moreover, the coefficient of the triple interaction with contract intensity is -0.146, implying that the observed negative effect is increasing in the degree of contract intensity. This finding aligns with our main research hypothesis, which pertains mostly

Table 6. *Heterogeneity: Education and Occupation*

	Education		Occupation	
Dep. var: ln(Wage)	College (1)	No college (2)	White-collar (3)	Blue-collar (4)
Female×Export/Sales×CI	-0.102***	-0.100***	-0.146***	0.006
	(0.030)	(0.028)	(0.035)	(0.025)
Female×Export/Sales	-0.020***	-0.012**	-0.016**	-0.002
	(0.007)	(0.006)	(0.007)	(0.006)
Match FE	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes
Observations	805,962	4,060,382	2,446,447	2,401,198
Adj R^2	0.949	0.904	0.946	0.807

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. Additional control variables included in all specifications are Experience, Experience$^2/100$, Children, College (columns (3) and (4)), White collar (columns (1) and (2)), and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

to white-collar workers since these workers are more likely to be involved in bargaining and customer service.[17]

As stated earlier, we expect that doing business with a variety of customers across the world changes the labor demand of firms and thus might shift the occupational composition. To investigate how an increase in exports might affect the employment composition of firms, we calculate the weighted average employment shares across four white-collar occupation categories and firm export intensity. To adjust for compositional differences across industries, we divide a firm's employment share in a particular category by its weighted industry average employment share, whereas industry is defined based on the 4-digit SNI2007 code. When obtaining weighted industry average employment shares, we consider all firms in the sample, both exporting and selling only domestically. We also divide firms into 4 subgroups: by contract intensity (firms in high VS low contract-intensive industries) and by export intensity (firms below VS above median export intensity). A value of 1 in Table 7 indicates that firm-level and industry-level weighted averages are equal or, in other words, firms of a particular type display a similar employment share as their counterparts operating in the same industry.[18]

When considering the results in Table 7, we notice at least two striking features in the employment composition of the two types of firms. Notably, both

[17] See Table A5 in the Appendix for heterogeneity results without the CI index, and Table A6 in the Appendix for more detailed heterogeneity results using the same model as in Table 6.

[18] Note that figures in Table 7 might happen to be all above or below 1 for a particular occupational category. If a firm's occupational share is substantially above that of the industry, it can generate outlier observations affecting the resulting figures. To circumvent this problem, we apply weighted average employment shares across industries and different firm types.

Table 7. *Firm occupational structure by contract intensity and firm export intensity*

	High CI		Low CI	
Export intensity	Below median	Above median	Below median	Above median
Managers	1.09	1.10	1.13	1.13
Sales workers	1.17	1.23	1.12	1.07
Tech workers	0.94	0.87	1.25	1.05
Support workers	1.03	0.99	1.03	0.98

Notes: The numbers represent weighted average shares of employment in firms divided by the weighted industry average employment shares, by occupation category. The firms are divided according to their industry-level contract intensity and their export activity (above and below median export intensity in the sample). The sample is a panel of all firms over the years 2001–2015.

high and low contract-intensive exporting firms employ relatively more managers compared to their industry average. Specifically, exporting firms with low CI index use 13 percent more management workers compared to firms in the same industry. At the same time, a corresponding figure for exporters in high contract-intensive industries remains around 1.10, meaning that these firms employ 10 percent more managers compared to an average firm in the same industry.

A more important finding for our paper, however, is that high contract-intensive firms rely more heavily on sales workers compared to their low contract-intensive counterparts. Namely, if we consider high CI firms with above median export intensity, we notice that the relative share of sales workers in these firms remains at 1.23. It means that these firms employ almost a quarter more sales personnel compared to other firms in the same industry. For high CI firms with below median export intensity, the corresponding figure is equal to 1.17, suggesting that shifts in the occupational structure are triggered by both the intensity of export operations and the type of goods sold. Overall, our findings lend support to the idea that depending on the degree of contract intensity, firms require a different set of skills of their workers and therefore exhibit slightly different occupational compositions. Such changes in the employment structure of high contract-intensive firms are consistent with them re-orienting operations towards more extensive trading activity, necessary to serve foreign markets.

To probe deeper into the heterogeneous effects of exports across white-collar occupations, we divide workers by four occupational categories outlined above and rerun the baseline specification separately for each subsample. The results in column (1) in Table 8 show that female managers, on average, are negatively affected by increased export intensity. The gender wage gap among managers is also increasing in contract intensity, as given by the negative estimate of the Female$\times$(Export/Sales)$\times$CI interaction term. Our results, therefore, suggest that changes in the task content, associated with higher export intensity, are more beneficial for male managers relative to female managers. We ascribe this finding to the male comparative advantage in particular tasks required by firms with a global reach. Negotiations, as discussed earlier, constitute one area where previous research has established that men outperform women. The increasing importance of activities related to negotiations serves as a plausible explanation for our findings for managers.

Table 8. *Occupations*

	White-collar occupations			
Dep. var: ln(Wage)	Managers (1)	Sales (2)	Tech (3)	Support (4)
Female×Export/Sales×CI	-0.144**	-0.131	-0.092***	-0.010
	(0.071)	(0.084)	(0.017)	(0.028)
Female×Export/Sales	-0.028	-0.024	-0.012***	-0.025***
	(0.017)	(0.018)	(0.004)	(0.008)
Match FE	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes
Observations	280,367	320,259	800,611	661,043
Adj. R^2	0.959	0.901	0.946	0.955

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. Additional control variables included in all specifications are Experience, Experience$^2/100$, Children, College, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

For sales personnel, we also observe an increasing gender wage gap for firms in high contract-intensive industries as a result of trade exposure. For this subgroup, we do not, however, find any significant effect of either the double or the triple interaction terms, but the size of the coefficients is around the same magnitude as for managers. One possible explanation for the lack of precision in column (2) may be that the category of sales workers is too broadly defined, encompassing both domestic and international sales workers. In column (3), we also find that the relative wages of female tech workers decrease when export intensity increases, and it does more so when a firm is operating in a more contract-intensive industry. The estimates of Female×(Export/Sales)×CI and Female×(Export/Sales) are -0.092 and -0.012, respectively, and are statistically significant. Finally, for support workers, as seen in column (4), the main effect of interest is small. We do, however, find an increasing gender wage gap among support workers when export intensity surges.

Taken together, the in-depth subgroup analysis reveals two important empirical facts about globalization and relative female wages. First, the relationship between export intensity and the gender wage gap, which is negative and increases in contract intensity, tends to hold for workers of all educational levels. More interestingly, intensified export in high contract-intensive industries appears to negatively affect the relative wages of white-collar female workers but exerts no effect on blue-collar female workers. Our results further indicate that the adverse effects on wages are most pronounced among managers and sales workers, although also present for tech and support female workers.

5.4 Mechanisms

Gender-biased rent sharing

We have demonstrated that globalized firms, depending on their need for bargaining skills and the associated degree of contract intensity, tend to reward their employees differently. Departing from this knowledge, it is reasonable to presume that the male comparative advantage in negotiations will probably be reflected in firm rent-sharing behavior too. In other words, the two types of firms will share rents in a different manner, depending on the nature of the goods they export. To explore this hypothesis, we perform a rent-sharing analysis following Card et al. (2016) and Bruns (2019), where we estimate a within-firm rent-sharing model across genders.[19] The exercise is reminiscent of the design employed in the preceding rent-sharing literature (Guiso et al., 2005; Card et al., 2014; Carlsson et al., 2016), but the estimation is performed on two disjoint samples of male and female workers. In this analysis, we therefore no longer rely on individual-level data and within-match identification, but instead zoom out to firm-level data and consider long-term differences in firm performance and average wages.

In essence, we examine within-firm variation in productivity (measured by excess value added per worker) and wages over time. The idea is to purge rent-sharing estimates from all time-invariant firm attributes by focusing on job stayers, i.e. workers who remain in the firm over a certain period of time (three years). This approach helps to eliminate biases generated by permanent firm heterogeneity and indicates whether the relative rent-sharing elasticity of female wages might vary across different types of firms. We believe that this exercise offers convincing evidence of potential gender differences in bargaining and the association with the degree of firm contract intensity.

Similar to Card et al. (2016) and Bruns (2019), we report both male and female rent-sharing coefficients and the bargaining ratios. The latter is obtained by running a two-stage IV regression of average wage changes of female stayers on average wage changes of male stayers, instrumented by excess log value added (the normalized measure of firm surplus), separately for the two types of firms. When obtaining average wage changes, we also estimate two specifications: a basic model, which includes year fixed effects, and an extended

[19] A detailed discussion of the model and the estimation procedure are presented in the Appendix.

Table 9. *Rent-sharing models for male and female three-year stayers (1997–2015, excess log value added)*

	Basic model			Extended model		
	Rent-sharing coef's			Rent-sharing coef's		
	Male (1)	Female (2)	Ratio M/F (3)	Male (4)	Female (5)	Ratio M/F (6)
Panel A. High CI firms, excess log value added per worker, 1997–2015, three-year stayers						
Three-year change, winsorized at $+/-0.75$	0.033	0.029**	0.895**	0.033*	0.028***	0.863***
	(0.022)	(0.012)	(0.367)	(0.017)	(0.010)	(0.199)
Three-year change, trimmed at $+/-0.75$	0.034	0.030**	0.897**	0.033*	0.029**	0.867***
	(0.025)	(0.013)	(0.396)	(0.019)	(0.011)	(0.224)
To restrictions	0.030	0.027**	0.896**	0.031**	0.027***	0.864***
	(0.020)	(0.011)	(0.351)	(0.016)	(0.009)	(0.188)
Panel B. Low CI firms, excess log value added per worker, 1997–2015, three-year stayers						
Three-year change, winsorized at $+/-0.75$	-0.004	0.010	-1.171	-0.007	0.000	-0.006
	(0.010)	(0.004)	(5.643)	(0.009)	(0.010)	(1.464)
Three-year change, trimmed at $+/-0.75$	0.004	0.009	2.231	0.002	0.007	4.257
	(0.010)	(0.010)	(3.877)	(0.009)	(0.010)	(17.005)
To restrictions	-0.003	0.003	-0.989	-0.006	-0.002	0.339
	(0.010)	(0.010)	(6.205)	(0.007)	(0.009)	(1.267)

Notes: The entries show coefficients of three-year wage changes of male and female stayers on three-year changes in excess log value added per worker. Wage changes are adjusted for a quadratic polynomial in age. Three-year changes in excess value added are adjusted for year fixed effects (the basic model) or year, 2-digit industry, and region fixed effects (the extended model). Ratios in columns (3) and (6) are obtained via two-stage least squares, instrumenting the male firm effect by log excess value added. All models are estimated at the firm-year level (domestic exporting firms only), weighted by the total number of person–years in the base year. Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

model, which includes year, 2-digit industry, and region fixed effects. The results are summarized in Table 9. Panel A and B report estimates for firms in high and low contract-intensive industries, respectively.

Already at first glance, we detect some differences in the rent-sharing behavior of firms. As seen in columns (1), (2), (4), and (5) of Panel A, high contract-intensive firms tend to share rents with their workers, and they do unevenly so with men versus women, as indicated by ratios in columns (3) and (6) of Panel A. More specifically, females' wages in high contract-intensive firms are only 86 to 89 percent as responsive to changes in firm productivity as male wages are.[20] On the other hand, the estimated coefficients in Panel B for firms in low contract-intensive industries are statistically insignificant in almost all specifications and also small in magnitude in columns (1), (2), (4), and (5), suggesting that these firms do not appear to share rents with their workers.

[20]Notably, unequal rent sharing across genders in the Swedish labor market context has been earlier outlined by Nekby (2003).

One issue with the rent-sharing analysis is that firm surplus tends to vary drastically over time, let alone its measurement difficulty. To probe whether large variability in firm productivity might introduce attenuation bias to the estimates, we use three versions of the three-year changes in the excess log value added per employee, as stated in the row names in Table 9. Winsorizing and trimming the variable does not affect either the rent-sharing coefficients, or the bargaining ratios in Panel A. The obtained estimates are, therefore, robust to alternative restrictions on the surplus measure and inclusion of industry and region fixed effects.

All things considered, the results suggest that firms in high contract-intensive industries share rents with their employees, whereas male workers benefit more from the increased firm surplus compared to female workers. On the contrary, we detect no rent sharing by low contract-intensive firms with either of the genders. Apart from facilitating men in export-related job tasks, the documented male comparative advantage in negotiations allows them to also claim higher rents compared to female workers. As expected, we find no evidence of rent sharing in low contract-intensive firms, since bargaining skills and other similar attributes are less needed in industries where buyer and seller do not interact as intensely.

Flexibility in working hours

As proposed by Goldin (2014) and tested empirically by Bøler et al. (2018) in the international trade context, the lack of temporal flexibility and/or commitment on behalf of female workers could explain the widening of the gender wage gap. There exists a possibility that high contract-intensive firms require more commitment from their employees when their export operations intensify. That is, the two types of firms may differ in their demand for temporal flexibility. To investigate this possibility, we examine how the flexibility hypothesis relates to firm contract intensity in shaping the gender wage gap in globalized firms. To this end, we subsequently exclude workers that are considered to be less flexible in time from the initial sample. In particular, we exclude workers: i) who have children between 0 and 6 years old, and ii) who are below 45 years old. We deem that both of these criteria allow us to identify workers who either have or plan for children and thus are more likely to be time-constrained.

In column (1) in Table 10, the baseline results from estimating model (1) for all workers are presented. These findings correspond to column (2) in Table 3, with an estimate of -0.118 for the interaction between the female dummy, export intensity, and the CI index, and -0.016 for the interaction between the female dummy and export intensity. Around one million observations in our sample belong to workers with young children, and these are excluded from the sample in column (2). When excluding workers with young children, the baseline estimates stay largely intact. In a similar vein, the exclusion of workers under 45 years old in column (3) does not challenge the baseline results

Table 10. *Robustness: Temporal flexibility*

Dep. var: ln(Wage)	Baseline (1)	No child 0-6 (2)	Age>44 (3)	High CI (4)	Low CI (5)
Female×Export/Sales×CI	-0.118***	-0.126***	-0.132***		
	(0.037)	(0.038)	(0.045)		
Female×Export/Sales	-0.016**	-0.014**	-0.015**		
	(0.007)	(0.007)	(0.007)		
Female×ln(BusHours)				-0.005	-0.002
				(0.003)	(0.004)
Match FE	yes	yes	yes	yes	yes
Firm×Year	yes	yes	yes	yes	yes
Observations	4,886,752	3,877,889	2,058,797	2,096,393	2,719,692
Adj. R^2	0.930	0.936	0.960	0.946	0.911

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. Additional control variables included in all specifications are: Experience, Experience$^2/100$, Children, College, White collar, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

either. The exclusion of workers under the age of 45 substantially shrinks the number of observations from around 4.9 million to 2 million, as people aged 18 to 44 constitute a vast majority of the workforce.

In addition to excluding time-constrained workers, we do another check and interact the female dummy with a firm's business hours overlap variable in columns (4) and (5) in Table 10. Following Bøler et al. (2018), the variable is constructed as an average business hour overlap across the exported country–product combinations relevant for a firm in a given year. Also in line with Bøler et al. (2018), the business hours overlap is calculated assuming standard office hours between 9.00 and 17.00 local time and using the average values for countries represented by multiple time zones. In a specification similar to model (1), the main interaction of interest is now replaced with Female×ln(Business hours overlap) variable. The results displayed in columns (4) and (5) indicate no difference between the two types of firms in the estimated effect of interest. In particular, the estimates are -0.005 and -0.002 for high and low contract-intensive firms, respectively, and neither of them reaches conventional significance levels. To sum up, the tests of the temporal flexibility hypothesis in this section provide no evidence of firms' contract intensity and the demand for worker commitment being necessarily related.

6 Conclusions

We add to the literature on globalization and gender inequality by analyzing how the nature of exported goods matters for the gender wage gap. We establish that export of goods in contract-intensive industries disproportionately benefits men, leading to a widening of the gender wage gap. We ascribe this result to men being better in negotiations compared to women. The negative impact on the gender wage gap is, however, limited to white-collar workers. Furthermore, we find the strongest effect among managers and sales workers, as compared to workers in other white-collar occupations, indicating that trade-related bargaining skills are particularly valuable in these occupations.

Arguably, cross-border transactions are subject to greater contracting and communication problems, especially if they occur with a foreign partner outside of the same company group. In line with this assumption, we find that the effect on the gender wage gap is strongest in the sample of domestic exporters, whereas there is no significant effect of increasing domestic sales on the gender wage gap. The former result suggests that the need for, and the remuneration of, bargaining skills is particularly large when firms operate with foreign contractors, external to the firm.

For the empirical analysis, we rely on matched employer–employee data from Sweden and estimate a multi-level fixed effects wage regression, subject to a range of specification tests. Our results are robust to alternative definitions of contract intensity, alternative model specifications, and the inclusion of more granular occupational fixed effects. When exploring the mechanisms behind our findings, we establish that men tend to claim higher rents relative to their female colleagues in industries where more buyer–seller interaction is needed. Male negotiation style appears to benefit them when there are rents to compete for in high contract-intensive firms. As an extension of the analysis, we also examine the complementary between firm contract intensity and commitment requirement and find no evidence of our results being driven by firms' demand for workers' temporal flexibility.

We attribute the increased gender wage gap in exporting firms to the male comparative advantage in bargaining. In relation to that, an interesting finding in psychology and behavioral literature is that women tend to be more cooperative, while men remain more competitive in negotiation situations. This suggests that firm trading partners are also likely to exert a certain impact on its wage-setting practices. We leave this intriguing question for future research—a question, we believe, can cast additional light on how globalization facilitates or hampers female labor market opportunities.

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Appendix A Tables

Table A1. *Variable definitions*

Variable	Source	Notes
Individual level		
Individual identifier	WSS	All individual identifiers are anonymized by Statistics Sweden using a serial number. The actual social security numbers come originally from the population register.
Wage	WSS	Full-time equivalent monthly earnings (comparable to hourly wage rates) relate to the survey month, usually September. The monthly wage data corresponds to the agreed-upon wage on top of amenities and variable incomes, absent overtime payments. The information is available for all employees in the public sector. In the private sector, the data are available for all workers in firms with at least 500 employees; for the rest, a stratified sample based on the industry affiliation and firm size is used. As a result, roughly 50 percent of private-sector workers are included in the sample in any given year. We use annualized and deflated data of wages expressed in EUR.
Occupation	WSS	Detailed information on worker occupation codes (up to 4 digits) is available from the salary structure statistics. The Swedish Standard Classification of Occupations (SSYK96) is based on the International Standard Classification of Occupations (ISCO-88). We define workers as white-collar workers if their one-digit occupation code is 1,2,3, or 4, and as blue-collar workers otherwise (occupation codes 5,6,7,8, or 9). A dummy variable for white-collar workers is included as a control variable in our main empirical specification.
Age	LISA	Individual's age, original source: the population register.
Gender	LISA	Individual's gender, original source: the population register.

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Table A1 – continued from previous page

Variable	Source	Notes
Education	LISA	We define a worker as having university education (as being skilled) if he or she has at least two years of post-secondary education. To derive the variable, we rely on the information on the highest completed level of education (original source: the education register). The original education variable takes on the following values: (1) Primary and lower secondary education, less than 9 years; (2) Primary and lower secondary education, 9 or 10 years; (3) Upper secondary education; (4) Post-secondary education, less than two years; (5) Post-secondary education, two years or longer; and (6) Postgraduate education.
Experience	LISA	The actual labor market experience of individuals is not available in our data. Instead we construct potential labor market experience as a difference between individual's age and (1) the year of obtaining highest level of education, or (2) years of education (based on the education variable). If neither of the variables are available, we subtract 16 to obtain potential labor market experience.
Children	LISA	The number of children below 18 years old is available from LISA database (original source: population register). We define a dummy taking a value of 1 if there is at least one child below 18 years old in the household.
Firm-level		
Firm identifier	FAD	The FAD-identifier is obtained from The Dynamics of Enterprises and Establishments Database (FAD, Statistics Sweden) and is developed to correct for administrative changes in firm legal identifiers over time and. The principle behind the FAD-identifier is that it remains the constant from one year to another if the firm's actual identifier has changed, but a majority of workers stay in the firm between the two consecutive years. More details on FAD-identifiers are available at Statistics Sweden website.

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Table A1 – continued from previous page

Variable	Source	Notes
Export of goods	Swedish Foreign Trade Statistics (SFTS)	The Swedish Foreign Trade Statistics covers Swedish export (and import) of goods broken down by destination country and (8-digit) type of goods classification. The data on goods trade cover the years 1997–2015. To measure goods export intensity, we use goods export sales over total sales (FEK) for each firm and year. This yields the export intensity measure varying between 0 and 1 for each firm–year observation.
Firm size	RAMS	To measure firm size, we aggregate the number of employees from the establishment level data (RAMS) to the firm level.
Sales	FEK	Sales is the firm's total turnover from goods and services in million EUR, deflated using CPI and turned from SEK into EUR using the Swedish central back annual average exchange rate. Excise duty is excluded, and the measure is also adjusted for merchanting.
Value added	FEK	Value added is defined as the firm's production value minus the cost of intermediate inputs. The measure does not include wages, social fees, or the cost of goods resold without processing, for which only the trade margin is included in the production value.
Export CI index	SFTS & Rauch, 1999	The export CI index reflects the ratio of all exported differentiated goods to the total firm–year export value. It builds on export data at the product-firm-year level combined with the Rauch, 1999 classification of goods. The Export CI index is constructed as an average over the first three years since 1997 (or since the first year of export).
Industry-level		
CI index	FEK & Nunn, 2007	The Nunn, 2007 contract intensity index is matched to firm data based on the Swedish industry classification SNI2007 (equivalent to NACE Rev.2) at the 4-digit level, which refers to firm main self reported economic activity.
SPIN CI index	SFTS & Nunn, 2007	The Nunn, 2007 contract intensity index is matched to firm data based on the Swedish product classification by industry (SPIN2007), such that SPIN2007 reflects a firm's main export product.

Table A2. *Export, contract intensity, and the gender wage gap: Alternative specifications*

Dep. var: ln(Wage)	(1)	(2)	(3)	(4)	(5)
Female×Export/Sales×CI	-0.014	0.023	0.024	-0.109**	-0.118***
	(0.066)	(0.067)	(0.067)	(0.043)	(0.037)
Female×Export/Sales	0.034***	0.038***	0.037***	-0.014*	-0.016**
	(0.012)	(0.012)	(0.012)	(0.008)	(0.007)
Female×CI	-0.022	-0.048*	-0.048*		
	(0.029)	(0.028)	(0.028)		
Export/Sales×CI	-0.139**	-0.070		-0.054	
	(0.055)	(0.043)		(0.042)	
Female	-0.186***	-0.188***	-0.190***		
	(0.037)	(0.036)	(0.037)		
Export/Sales	0.031***	-0.000		0.005	
	(0.009)	(0.009)		(0.008)	
CI	0.094***				
	(0.024)				
ln(Sales)	0.026***	0.013***		0.011***	
	(0.003)	(0.003)		(0.003)	
Female×ln(Sales)	0.002	0.002	0.002	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Experience	0.017***	0.017***	0.017***	0.009***	0.009***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
Experience^2/100	-0.029***	-0.028***	-0.028***	-0.030***	-0.029***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Children	0.027***	0.027***	0.027***	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
College	0.254***	0.246***	0.245***	0.081***	0.077***
	(0.006)	(0.006)	(0.006)	(0.003)	(0.003)
White collar	0.237***	0.236***	0.237***	0.034***	0.035***
	(0.007)	(0.007)	(0.007)	(0.005)	(0.005)
ln(Firm size)	-0.013***	-0.015**		0.013***	
	(0.004)	(0.007)		(0.005)	
Industry×Year FE	yes	yes	yes	yes	no
Firm FE	no	yes	no	no	no
Firm×Year FE	no	no	yes	no	yes
Match FE	no	no	no	yes	yes
Observations	4,886,752	4,886,752	4,886,752	4,886,752	4,886,752
Adj R^2	0.532	0.561	0.565	0.926	0.930

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A3. *Average Wages across Educational Specialization*

Specialization	High CI All	High CI Female	High CI Male	High CI Ratio	Low CI All	Low CI Female	Low CI Male	Low CI Ratio
All workers								
Law	5,270.45	4,663.98	5,748.91	0.81	4,464.59	4,116.52	4,698.73	0.88
Business and economics	3,699.09	3,306.98	4,110.61	0.80	3,291.29	2,955.29	3,585.27	0.82
Health and medicine	3,108.94	2,922.06	3,489.00	0.84	3,133.08	2,946.23	3,860.76	0.76
Natural science	4,190.61	3,899.96	4,302.19	0.91	3,647.29	3,454.60	3,742.86	0.92
Teaching	3,643.30	3,416.26	3,828.79	0.89	3,136.76	3,039.08	3,227.65	0.94
Engineering	3,614.55	3,679.65	3,608.79	1.02	3,158.47	3,207.02	3,154.61	1.02
Social sciences	4,244.31	3,812.79	4,612.46	0.83	3,664.44	3,275.28	4,002.75	0.82
Services	2,686.84	2,597.44	2,841.66	0.91	2,662.77	2,565.55	2,808.54	0.91
Other specialization	3,314.31	3,072.67	3,417.63	0.90	2,967.50	2,795.05	3,050.19	0.92
No specialization	2,832.14	2,676.99	2,887.26	0.93	2,747.63	2,559.32	2,819.30	0.91
White-collar workers								
Law	5,342.69	4,707.26	5,850.89	0.80	5,526.35	4,586.86	6,412.23	0.72
Business and economics	3,940.35	3,432.18	4,540.98	0.76	3,727.64	3,178.64	4,296.71	0.74
Health and medicine	3,598.85	3,279.22	4,346.96	0.75	3,355.98	3,080.08	4,767.03	0.65
Natural science	4,300.13	3,962.35	4,434.51	0.89	3,993.40	3,655.62	4,188.32	0.87
Teaching	3,957.22	3,615.30	4,279.64	0.84	3,619.83	3,364.67	3,937.25	0.85
Engineering	4,176.54	3,936.87	4,206.62	0.94	3,880.59	3,620.53	3,916.47	0.92
Social sciences	4,395.87	3,900.67	4,837.50	0.81	4,268.39	3,580.27	4,986.49	0.72
Services	2,983.65	2,829.62	3,382.92	0.84	2,959.67	2,761.10	3,313.90	0.83
Other specialization	3,871.02	3,379.91	4,147.47	0.81	3,574.92	3,159.37	3,854.19	0.82
No specialization	3,306.85	2,962.86	3,546.03	0.84	3,191.55	2,792.17	3,428.66	0.81

Notes: All numbers refer to average values of the monthly wages (EUR) for the panel of worker-level data for 1997–2015. The numbers are presented for all and white-collar workers and across workers' educational specialization, as indicated by the row headings. Workers belong to high (low) contract-intensive industry if the CI index of their employer is above (below) the median CI index in the sample.

Table A4. *Export and the gender wage gap: Alternative specifications*

Dep. var: ln(Wage)	(1)	(2)	(3)	(4)	(5)
Female×Export/Sales	0.034***	0.039***	0.039***	-0.025	-0.029**
	(0.013)	(0.013)	(0.014)	(0.015)	(0.014)
Female	-0.173***	-0.168***	-0.169***		
	(0.035)	(0.036)	(0.036)		
Export/Sales	0.032***	-0.003		0.005	
	(0.010)	(0.010)		(0.009)	
Industry×Year FE	yes	yes	yes	yes	no
Firm FE	no	yes	no	no	no
Firm×YearFE	no	no	yes	no	yes
Match FE	no	no	no	yes	yes
Observations	4,886,752	4,886,752	4,886,752	4,886,752	4,886,752
Adj R^2	0.532	0.561	0.565	0.926	0.930

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. Additional control variables included in all specifications are: Experience, Experience$^2/100$, Children, College, White collar, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A5. *Export and the gender wage gap: Heterogeneity by education and occupation*

	Education		Occupation	
Dep. var: ln(Wage)	College	No college	White-collar	Blue-collar
Female×Export/Sales	-0.038***	-0.020*	-0.039**	-0.002
	(0.012)	(0.011)	(0.018)	(0.005)
Match FE	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes
Observations	805,962	4,060,382	2,446,447	2,401,198
Adj R^2	0.949	0.904	0.946	0.807

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. Additional control variables included in all specifications are: Experience, Experience$^2/100$, Children, College (columns (3) and (4)), White collar (columns (1) and (2)), and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A6. *Heterogeneity: Education and Occupation*

	White Collar		Blue Collar	
Dep. var: ln(Wage)	College (1)	No college (2)	College (3)	No college (4)
Female×Export/Sales×CI	-0.099***	-0.150***	0.065	0.004
	(0.030)	(0.037)	(0.138)	(0.024)
Female×Export/Sales	-0.020***	-0.015**	-0.059*	-0.002
	(0.008)	(0.007)	(0.031)	(0.005)
Match FE	yes	yes	yes	yes
Firm×Year FE	yes	yes	yes	yes
Observations	778,542	1,659,337	23,451	2,381,254
Adj R^2	0.95	0.94	0.85	0.81

Notes: Estimates are based on the worker-level panel data over 1997–2015, whereas workers employed in domestic exporting firms are considered. Additional control variables included in all specifications are Experience, Experience$^2/100$, Children, and Female×ln(Sales). Standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Appendix B Rent Sharing

To evaluate the relative rent-sharing elasticity of female wages across high and low contract-intensive firms, we examine how variation in firm productivity relates to its average wages over time. In this analysis, we focus on job stayers, i.e. workers who remain in the firm over a certain period of time. That allows us to adjust the rent-sharing estimates for time-invariant firm attributes and eliminate the associated bias.

Following Card et al. (2016), denote individual worker by $i \in \{1,\dots N\}$ over period $t \in \{1,\dots T\}$, worker i's gender as $G(i) \in \{M,F\}$, and his or her employer in year t by $J(i,t) \in \{1,J\}$. Assume further that

$$S_{jt} = \lambda \max\left\{0, S^0_{jt} - \tau\right\} + \varsigma_{jt} \equiv \lambda NS_{jt} + \varsigma_{jt} \tag{B1}$$

where S_{jt} is an actual surplus per worker for firm j in year t, also defined as net surplus; S^0_{jt} is an observed surplus measure for firm j in year t; τ is a threshold value under which the net surplus shared by firms is assumed to be zero, as explained in more detail below; and ς_{jt} is an error term with mean zero. Using a theoretical model outlined in Card et al. (2016), one can derive the following equation:

$$\begin{aligned}\mathbb{E}\left[w_{iT} - w_{i1} | NS_{J(i,1)1}, NS_{J(i,1)T}, X_{i1}, X_{iT}, G(i), stayer\right] \\ = (X_{iT} - X_{i1})'\beta^{G(i)} + \theta^{G(i)}\left[NS_{J(i,1)T} - NS_{J(i,1)1}\right]\end{aligned} \tag{B2}$$

where $\theta^{G(i)} = \lambda\gamma^{G(i)}$ and *stayer* is shorthand for conditioning on worker i being continuously employed at the same firm j throughout the sample period.

By running an OLS regression of model (3), we obtain estimates of θ^M and θ^F, ultimately providing the estimate of the relative rent-sharing elasticity across genders, or the so called *bargaining ratio*, $\frac{\gamma^F}{\gamma^M}$. Finally, according to the Card et al. (2016) model, the bargaining ratio relates to the average wage changes of male and female stayers. Formally:

$$\frac{\mathbb{E}\left[w_{iT} - w_{i1} - (X_{iT} - X_{i1})'\beta^F | female, stayer, J(i,1) = j\right]}{\mathbb{E}\left[w_{iT} - w_{i1} - (X_{iT} - X_{i1})'\beta^M | male, stayer, J(i,1) = j\right]} = \frac{\gamma^F}{\gamma^M} \tag{B3}$$

In the analysis, equation (4) is estimated using a two-step IV approach. To this end, a regression of change in wages on covariates and firm dummies is run separately by gender to produce residualized average firm wage changes. In the second step, the adjusted average change in female wages is regressed upon the corresponding average male change, instrumented by the change in measured surplus and weighted by the total number of stayers at the firm.

Getting back to the threshold τ, when obtaining the residualized wage changes from the two disjoint samples, one has to normalize firm effects to make them comparable across samples. It means we need to impose a linear restriction on the firm fixed effects such that they are identified with respect to the same reference firm or firms. According to the Card et al. (2016) model, the true firm effects are non-negative and are equal to zero for firms offering no surplus. Hence, imposing the following restriction provides a set of normalized firm effects coinciding with their true counterparts:

$$\mathbb{E}\big[\psi^{G(i)}_{J(i,t)}|\bar{S}^{0}_{jt} \leq \tau\big] = 0 \qquad G(i) \in \{M,F\}, \tag{B4}$$

where $\psi^{G(i)}_{J(i,t)}$ are gender-specific firm effects. The coefficient τ is then identified by simultaneously estimating the two equations of labor productivity and firm effects across genders. The threshold for no-surplus firms is derived at the point where the coefficient of determination is the highest. The estimated threshold is used to obtain the *excess log value added*—a normalized version of the firm surplus.

Appendix C Female Share of Employees

We have found a negative effect of export intensity on the relative female wages that gets more pronounced with contract intensity. In this section, we examine whether firms in high contract-intensive industries change gender workforce composition to a larger extent than their low contract-intensive counterparts when export intensity surges. The firm-level yearly female shares are calculated as the number of female employees divided by the total number of employees in the respective category, indicated in the column headings in Table C1. In this analysis, we consider both part-time and full-time workers, unlike other parts of the paper where only full-time workers are examined. A firm-level model can be written as follows:

$$\begin{aligned} FemaleShare_{jkt} = & \beta_1 Export_{jt} + \beta_2 [Export_{jt} \times CI_k] \\ & + \beta_3 DomSales_{jt} + \beta_4 [DomSales_{jt} \times CI_k] \\ & + \eta_{kt} + \eta_j + \varepsilon_{jkt} \end{aligned} \tag{C1}$$

where $FemaleShare_{jkt}$ is the share of female workers in firm j in industry k observed in year t and other variables are defined as before. We choose to include domestic sales, $DomSales_{jt}$, and its interaction with the CI index, $DomSales_{jt} \times CI_k$, to control for its potential effects on the female labor share. In addition to that, we consider two sets of fixed effects in model (4): (i) industry–year fixed effects (η_{kt}), and (ii) firm fixed effects (η_j), and thereby adjust for systematic variations in workforce composition across industries, as well as for unobserved time-invariant firm characteristics.

As shown in Table C1, the interaction between export intensity and the CI index shows no significant correlation with the female share of employees in any of the studied groups. That is, we do not find any evidence of high contract-intensive firms hiring females in a different proportion compared to low contract-intensive firms as their export intensity increases. Instead, we find that higher export intensity appears to be correlated with an increase in the overall share of female employees, as stated in column (1), and also with the shares of white-collar females (column (2)). This could indicate a higher skill intensity of exporting firms. An increased export intensity does not, however, seem to significantly correlate with the female share of blue-collar workers in column (3), college-educated workers in column (4), or newly hired workers in column (5). Hence, export intensity appears to correlate with the gender composition of the firm, particularly when it pertains to workers in white-collar tasks, but the correlations tend to be the same across firms with different degrees of contract intensity.

Table C1. *Female share of employees*

	All (1)	White Collar (2)	Blue Collar (3)	College (4)	New Hire (5)
Export×CI	-0.019	0.012	0.033	-0.058	-0.000
	(0.036)	(0.060)	(0.278)	(0.095)	(0.136)
Export	0.012*	0.030***	-0.007	0.017	-0.006
	(0.006)	(0.011)	(0.061)	(0.017)	(0.024)
Domestic Sales×CI	0.001	0.026	0.183***	-0.004	0.097
	(0.026)	(0.021)	(0.070)	(0.042)	(0.072)
Domestic Sales	0.001	0.007*	-0.029***	-0.003	0.010
	(0.005)	(0.004)	(0.011)	(0.006)	(0.012)
Industry×Year FE	yes	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes	yes
Observations	24,761	19,138	19,138	19,240	21,787
Adj R2	0.961	0.839	0.599	0.798	0.459

Notes: The dependent variable is female share of all employees in column (1), female share of white collar employees in column (2), female share of blue collar employees in column (3), female share of college educated employees in column (4), and female share of new hires in column (5). Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Essay III. The R&D and Innovation Effects of Firm-Specific Trade Opportunities

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1 Introduction

International trade and technological innovations are two of the most important drivers of a changing global economy. Both forces have potentially large impacts on aggregate welfare and inequality. Yet, we know surprisingly little about how they interact. In this paper, I use Swedish register data to investigate how international trade in the form of export and import opportunities affects firm-level R&D investments and innovation outcomes.[1]

To ensure a direction of causality from export and import opportunities to R&D and innovation, I build on the insights from Hummels et al. (2014) and Aghion et al. (2022) and relate initial firm-specific trade patterns to changes in global trade patterns. By exploiting the fact that firms differ in their product-country exporting and sourcing patterns, I construct measures of firm-specific trade opportunities arising from differences in how exposed firms are to changes in international trade flows. The variables are exogenous to firm-level decisions and only respond to aggregate conditions in a firm's export destinations and import origins. The empirical strategy relies on the assumption that firms' trade patterns are persistent, which holds true in the data; after 16 years, the initial country-product trade pattern still reflects around 40 percent (37 percent) of the total export (import) value.

One contribution of the paper is to build trade-opportunity variables that reflect the trade partners' comparative demand or supply changes. The export (import) opportunities are computed as the share of country-product exports (imports) out of the total world exports (imports) in the same product category. Using world-trade shares ensure that the change in country-product trade is not confounded by a general change in the product-specific demand (supply). I validate the relevance of the trade-opportunity variables by estimating the impact of export (import) opportunities on trade volumes and prices within a set of granular product-country-firm fixed effects models. The results show clear impacts of trade opportunities on trade volumes. Moreover, prices are increasing when export opportunities are improving, but there is no statistically significant effect on prices from improved import opportunities.

To analyze the firm-level growth and innovation responses, I use detailed economy-wide Swedish register data covering the years 1997-2014. International trade data from COMTRADE and firm-level trade data from Statistics Sweden are matched to create export demand and import supply. Sweden is a trade-dependent economy with a total trade value corresponding to around 90 percent of its GDP. Furthermore, Sweden is currently ranked as the third most innovative country in the world (World Intellectual Property Organiza-

[1]From the literature on endogenous growth, we know that R&D, innovations and the spillover effects from these activities are among the main contributors to growth in total factor productivity, and thereby welfare in developed countries. See, e.g., Jones (2016) for a summary of the literature on economic growth.

tion, 2022), and the R&D spending is around 3.3 percent of GDP.[2] The combination of high trade dependency and high innovation rate, as well as the high-quality register data, makes Sweden an ideal case when investigating the link between trade opportunities and innovative activities.[3]

In the main analysis, I aggregate product-country-specific export and import opportunities to the firm level using initial trade patterns as weights. I first estimate firm-fixed effects models where exogenous variations in trade opportunities are allowed to impact key firm-level outcomes. The results show that firm-specific export and import opportunities have large positive effects on a wide range of firm-performance measures. Increased trade opportunities of either type affect firm growth in terms of sales, value-added, and overall employment. Moreover, the employment effects do not appear to be limited to low-skilled production workers; the impact on high-skilled employees (including Ph.D:s) is proportional to the overall employment effect.

In the next step, I analyze how these two growth-inducing trade shocks affect R&D and innovations. My results indicate that export and import opportunity shocks, despite the similar impact on firm growth, have very different impacts on firms' innovative activities. I find a positive relationship between opportunities to export (i.e. an increase in the potential market size) and R&D spending, R&D employees, and product and process innovation. In contrast, a rise in the opportunity to import does not significantly affect any of the R&D outcomes. Product, process, and service innovation are, however, negatively affected - a finding in line with the suggestion that imported intermediates are complements to some R&D activities but substitutes to in-house innovation. Industry-year fixed effects are included in all empirical specifications to ensure the results are driven by firm-level changes to R&D and innovation within industries, and not by industry-year-specific shocks.

Overall, the results suggest a positive causal link between firm-specific export opportunities and innovative activities. The findings contribute to the literature on how international trade affects R&D and innovations, where Aghion et al. (2022) are the closest related example. They study the heterogenous effects of market size on innovation in terms of priority patent filings among French firms. Chalioti et al. (2020) also study exports and innovation, where innovation is measured as international patent activity. They show that innovative firms sell higher quantities instead of increasing their prices. Similarly, Aw et al. (2011) document a direct link between export and R&D investment. Estimating a dynamic structural model using data from Taiwanese firms, they show that both exporting and investing in R&D endogenously affect future productivity gains, which leads to self-selection into both activities. The papers by Chalioti et al. (2020) and Aw et al. (2011) underline the importance

[2]Data on Sweden's trade dependency and R&D spending come from the World Bank Data: https://data.worldbank.org (downloaded February 9, 2022).

[3]See Figure A1 in the Appendix for an illustration of the positive correlation between changes in openness to trade and country-level R&D spending.

of using trade opportunities that are correlated with the firm's decision to increase trade, but exogenous to the R&D investments and/or innovative ability of a firm to avoid simultaneity bias. The relationship between expanding market access from trade liberalization and innovation is studied by Coelli et al. (2022). They find evidence that innovation measured by patents grows with trade liberalization, and thereby enhances growth. Although I do not study trade policy directly, I relate to their paper by investigating the effects of larger market size on innovation. The R&D variables and different modes of innovation in this paper also complement studies utilizing patent data. Furthermore, R&D and innovation responses may reflect more instant and diverse changes in innovation compared to those limited to patent filings as outcomes.

Two other influential papers documenting the export-R&D link are Lileeva and Trefler (2010) and Bustos (2011), who study the extensive margin of exports, i.e. their export status, and use R&D spending as their outcome. Both find an explicit relationship between export status and R&D spending. With few exceptions, where Dhingra (2013) and Flach and Irlacher (2018) are two notable ones, innovation in trade models is one-dimensional and makes no distinction between product and process innovation. In reality, firms may face the choice between lower production costs (process innovation) or expanding their product range/quality upgrading (product innovation). In contrast to my paper, these studies only evaluate demand-side effects, whereas I investigate supply-side effects as well. The focus on both demand and supply may yield a better understanding of firm behavior in relation to product and process innovation, and decisions about R&D investments and innovation in general.[4]

Turning to the import side, studies investigating the impact of imports on firms' innovation-related outcomes mostly focus on developing countries.[5] With this said, two outcomes have been investigated to a larger extent in developed countries: labor composition and wages (see for example Hijzen et al. (2005) and Hummels et al. (2014)). The effect of international trade on domestic R&D, however, has not been as thoroughly investigated empirically in developed countries. A few important and relevant exceptions are found in the empirical literature. Karpaty and Tingvall (2015) investigate how offshoring of intermediate inputs impacts home country R&D in Sweden. They find a substitution effect of material imports on the firm's own R&D for small firms, but for the largest firms, the effect of offshoring is positive on in-house R&D investments. Based on these findings, they draw the conclusion that firms are

[4]The finding of better export opportunities leading to more R&D investments also fits with the finding of Maican et al. (2022) who estimate a dynamic structural model of firm R&D investment in Swedish manufacturing industries. They show that the expected return to R&D is larger in export markets due to faster productivity growth there compared to the domestic market. An exogenous shock leading to a growing export market should therefore make it more profitable for the firm to invest in R&D.

[5]See Shu and Steinwender (2019) for a literature review of studies of trade liberalization on innovation.

heterogeneous in their R&D response with respect to the offshoring decision. For Norway, Bøler et al. (2015) find a complementary effect between R&D and imports. By introducing imported inputs into a model of R&D and endogenous productivity, they do not find a decrease in imported inputs from an R&D tax credit introduction. On the contrary, cheaper R&D leads to both more R&D and more imports of intermediates, which speaks in favor of a complementary link between imported intermediates and R&D investments. On the other hand, cheaper imported intermediates have also been shown to substitute in-house R&D spending and innovation, as found by Q. Liu and Qiu (2016). When import prices fall, firms may buy new inputs instead of innovating themselves. Furthermore, studies of import competition in the US on R&D and innovation show mixed results (Autor et al., 2020; Hombert and Matray, 2017; Chakravorty et al., 2017; R. Xu and Gong, 2017). Based on previous research, it is not obvious what we should expect from the link between imports and R&D/innovation. If better import opportunities lead to less or more R&D investments and innovation, and what governs the result, still requires further research.

The existing literature on international trade, R&D, and innovations investigates changes in either exports or imports. As stressed in Steinwender (2015), papers concentrating on one of them miss the other important channel, which could have a very different impact on innovative activities. This highlights the significance of evaluating both exports and imports and contrasting the signs and sizes of the effects, which is one contribution of my paper. Other contributions of my paper are the way export demand and import supply are constructed as shares of world trade to reflect changes in country-product comparative advantages, and the use of rich economy-wide register data for a trade-dependent and highly innovative country. Two main takeaways of the paper are, first, the joint growth-enhancing effects of both trade shocks, showing firms grow along multiple dimensions regardless of demand or supply triggering the change. And secondly, the very different impacts of the trade shocks on innovative activities, which underline the importance to consider both exports and imports when evaluating the connections between trade and technological innovations.

The paper proceeds as follows. The data, empirical framework, and summary statistics are outlined in section 2. Section 3 presents and discusses the results. Finally, section 4 highlights the main findings of the paper and concludes.

2 Data and Empirical Framework

2.1 Data

To investigate the link between firm-specific trade opportunities and R&D and innovation, firm-level accounts data, individual-level data, and customs trade data from Statistics Sweden are combined with international trade data from the UN COMTRADE database covering the years 1997-2014. Information on firm-specific imports and exports at the country-product-year level is drawn from the Swedish customs trade data.[6] The international country-product trade flows for each year are matched to the Swedish exports and imports data to construct the export demand and import supply variables. The exact procedure of the construction of the trade-opportunity variables is described in section 2.2. The firm-level accounts data cover all sectors of the economy. A number of variables are collected from the accounts data including: sales, value-added, number of employees, wages, and industry codes.

The R&D and innovation outcome variables come from two different surveys conducted every other year - the R&D survey (FoU) and the Community Innovation Survey (CIS). The R&D survey covers every other year between 1997-2013, and has information on the yearly R&D expenditure in SEK and the number of full-time equivalent R&D employees. In total, there are nine waves of the R&D survey in the data, and approximately 1,000 firms are surveyed in each wave. From the R&D survey responses, I construct four R&D outcome variables: the log of R&D expenditure, R&D expenditure over total sales, the log of the number of R&D employees, and finally, the number of R&D employees over the total number of employees. There are six waves of the Community Innovation Survey in the data, covering every other year from 2004 until 2014. Each wave asks innovation-related questions about the present year plus two years back in time. For example, the CIS2014 covers the years 2012-2014, which yields an overlap across the waves. The number of sampled firms grow over the years from approximately 3,200 firms in CIS2004 to 8,100 firms in CIS2014. When the years overlap, the CIS responses of the earlier survey are assigned. For example, if a firm answered they did a product innovation in CIS2012 and no product innovation in CIS2014, the year 2012 will be assigned a product innovation since it is more likely that the answer closer to the actual year in question is correct. The variables for product, process, and service innovation are dummy variables that take on the value one if the firm has made such an innovation during the period in question, and zero otherwise. Product innovation is defined as a "New or significantly improved good", and is an indicator of quality upgrading or variety expansion. Likewise, a service innovation is a "New or significantly improved service." New goods or services purchased from other firms and simply resold are excluded from these categories. As are changes to products of a solely aesthetic nature. Process innovation is defined as a "New or significantly improved production method" or a "New or significantly improved supporting activities for

[6] All trade with countries outside the EU (Extrastat) is registered at the Swedish customs and therefore covered by the data. Data on trade with other EU countries are collected via a total population survey subject to a trade value threshold. This implies that trade within the EU for the smallest firms is not recorded in the data. In addition, the survey data are complemented with VAT declarations submitted to the Swedish Tax Agency.

your processes, such as maintenance systems or operations for purchasing, accounting, or computing." Process innovation can be seen as a way for the firm to reduce costs and improve efficiency.

The largest Swedish firms are sampled in both the R&D survey and the CIS, but the surveys also include a stratified random sample of firms, where firms are stratified according to industry affiliation and firm size. All data are matched at the firm-year level, and all variables in SEK are deflated using PPI with the base year 2010. Variables expressed in USD are first converted to SEK and subsequently deflated.

2.2 Empirical Framework

The empirical strategy in this paper builds on the outcome variables being regressed directly on the trade-opportunity variables, equivalent to a reduced-form regression, as in Aghion et al. (2022). The interpretation of the coefficients is therefore in terms of changes in the trade-opportunity variables and reflects what happens with firm growth, R&D investments, and innovations when trade opportunities change, and not the levels of exports and imports themselves. The estimation strategy adopted can be contrasted to an instrumental variable strategy where the trade-opportunity variables are used as instruments for the firm's exports and imports values. The key argument for the reduced form estimation strategy is that both exports and imports, as well as R&D expenditure and innovations, depend on firm decisions. Hence, they are both endogenous to the firm, whereas the more direct focus on trade opportunities can be interpreted as an exogenous opportunity to reach a larger market (export demand), or as an exogenous opportunity to buy inputs at a lower price or of higher quality (import supply). Export demand thus reflects an expansion of the potential export/product market, whereas import supply reflects the cost-reducing import opportunities faced by the firm, which may affect other margins of the firm in addition to trade. Furthermore, the literature suggests that firms may react directly to changes in their trade opportunities, see Shu and Steinwender (2019) for a summary of the literature on trade opportunities and innovation.

2.3 Trade Opportunities: Export Demand and Import Supply

The aim of the paper is to study how firm-level export and import opportunities affect firm growth, R&D investments, and innovation. Using realized exports and imports values and patterns from the firm-level data to measure trade opportunities would expose the analysis to the threat of reversed causality. Instead, I rely on variables of trade opportunities that are exogenous to the individual firm. The export demand and import supply variables are constructed to reflect changes in the comparative demand or supply of the country-product combination exported or imported by the firm. To construct these variables at the firm level, we need export demand and import supply variables at the country-product-year level combined with firm-level trade exposure weights. The two pieces are built separately and then aggregated in order to obtain variables at the firm-year level. The export demand variable is the share of world import demand (ED_{ckt}), and the import supply variable is the share of world export supply (IS_{ckt}). Export demand and import supply are inspired by, but not identical to, the trade shocks in levels in Hummels et al. (2014), and the export growth rates in Aghion et al. (2022). The main difference compared to Hummels et al. (2014) is that I divide the trade shock with the world demand or supply of the product, changing the variables from levels to shares. The share reflects a change in the comparative demand or supply of the specific country-product combination, instead of a general world demand or supply shock.

The export demand variable is country c's total purchases of product k at the world market, minus its purchases of product k from Sweden in year t, divided by world purchases of product k minus world purchases of product k from Sweden in year t:

$$ED_{ckt} = \frac{ImportWorldValue_{ckt} - ImportSwedenValue_{ckt}}{ImportWorldValue_{kt} - ImportSwedenValue_{kt}} \tag{2}$$

The import supply variable is country c's total supply of product k to the world market minus its supply of product k to Sweden in year t, divided by the world's supply of product k minus the supply of product k to Sweden in year t:

$$IS_{ckt} = \frac{ExportWorldValue_{ckt} - ExportSwedenValue_{ckt}}{ExportWorldValue_{kt} - ExportSwedenValue_{kt}} \tag{3}$$

To test and validate the trade-opportunity variables, I regress trade values, volumes (weight), and prices (value/weight) on ED_{ckt} and IS_{ckt} separately. The estimated regression looks as follows:

$$ln(Y_{jckt}) = \alpha_{jck} + \gamma ED_{ckt} + \tau_t + \varepsilon_{jt} \tag{4}$$

where $ln(Y_{jckt})$ is the logarithm of either export values, volumes, or prices for firm j of product k exported to country c in year t. α_{jck} captures firm-country-product fixed effects, ED_{ckt} is the export demand variable, and τ_t represents the year fixed effects.

For import supply, the regression is identical apart from the two differences that $ln(Y_{jckt})$ now represents the value, volume, or price of firm j's imports of product k from country c in year t, and that ED_{ckt} is replaced with IS_{ckt}:

$$ln(Y_{jckt}) = \alpha_{jck} + \beta IS_{ckt} + \tau_t + \varepsilon_{jt} \quad (5)$$

I validate the relevance of the trade-opportunity variables by estimating the impact of export and import opportunities on values, volumes, and prices within product-country-firm fixed effects models. For both exports and imports, better opportunities to trade within a given country-product category should lead to larger volumes traded. Moreover, we would expect a price increase from a surge in opportunities to reach a bigger market. On the other hand, we do not expect a price increase from improved import opportunities. Here unchanged prices, or possibly negative price changes, are more reasonable when the supply of the imported country-product combination goes up. The results in Table 1 show a rise in both trade volumes and prices from improved export opportunities, while improved import opportunities lead to an increase in trade volumes but no significant effect on prices. These results are in line with what we would expect.

Table 1. *Export Demand and Import Supply*

	(1)	(2)	(3)
Dependent variable :	ln(value)	ln(volume)	ln(price)
Panel A. Export Demand			
Export Demand$_{ckt}$	2.494***	2.283***	0.212*
	(0.201)	(0.159)	(0.117)
Observations	7,124,414	7,124,414	7,124,414
Panel B. Import Supply			
Import Supply$_{ckt}$	1.697***	1.659***	0.038
	(0.136)	(0.149)	(0.031)
Observations	5,401,146	5,401,146	5,401,146
Firm×Country×Product FE	yes	yes	yes
Year FE	yes	yes	yes

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The responses in both value and volume in Table 1 are quite sizable. In Panel A, a one percentage point change in export demand yields a response in export value of 2.5 percent, and in volume of 2.3 percent. The price response is approximately 0.2 percent from a one percentage point shock to export demand. Comparably, as given by Panel B, import value and volume will both respond by approximately 1.7 percent when import demand changes by one percentage point. The price change is, however, small and not statistically significant. Overall, the results support the interpretation that export opportunities can be interpreted as a shock to product demand and import supply can be interpreted as a shock to the supply of intermediate inputs.

2.4 Firm-Level Exposure Weights

The firm growth, R&D investment, and innovation outcomes of interest are at the firm-year level, but the variation in the ED_{ckt} and IS_{ckt} variables described above is at the country-product-year level. To construct export demand (import supply) at the firm-year level, exposure weights W^E_{jck} (W^I_{jck}) of the share of country-product exports (imports) for firm j in the first year the firm exports (imports) are needed. In the spirit of a Bartik (1991) standard shift-share setting, fixing the firm-level exposure weights in the initial period will exclude all endogenous variation in the country-product export or import patterns of the firm due to changes in either export demand or import supply. In this paper, the initial period is the first year the firm records exports and imports, and thus it may vary across firms. The first year for each firm is, however, subsequently excluded from the analysis. Since the shift-share setting is incomplete, with a sum of the exposure weights over countries and products not equal to one, I control for the sum of the exposure weights interacted with a time dummy in the regression, as suggested by Borusyak et al. (2021). Furthermore, the identification strategy includes firm-fixed effects and relies on the assumption of random assignments of the trade shocks (shifts), and allows the trade exposure weights (shares) to be endogenous.

The persistence in the firm-level trade exposure weights is important for the validity of the trade-opportunity variables. If the initial trade pattern of the firm is solid over time, it is more likely that we will capture the relevant trade opportunities in each period. To evaluate the persistence in initial export and import weights, we can look at Figure 1, where the average trade weights at the country-product, country, and product levels are displayed. The left panel of Figure 1 shows the export weights, and the right panel shows the corresponding import weights.

In the left panel in Figure 1, the average share of total export value for the initial time period country-product weights (W^E_{jck}) is illustrated by the blue dots. The first period on the x-axis represents the first year export from the firm is observed, and this is the point in time when the firm's country-product weights are determined. On average, the original country-product export basket constitutes more than 70 percent of the second year's export value. The mean share of the original export weight seems to stabilize at 40 percent after ten years, and after 16 years it still reflects around 40 percent of the total export value. This finding indicates that country-product trade patterns are persistent and that the export exposure weights capture a relevant proportion of firm-level trade in each period. As an additional exercise, the country and product trade weights are studied separately to get insights into how firms change their export-destination mix and export-product mix over time. The red diamonds show that the initial export destinations still reflect, on average, 75 percent of the export value after 16 years. It seems as the countries the firm starts to export to remain important export destinations throughout the period of study. The original export-product basket drops to approximately 60 percent of the export value in the final period studied, as illustrated by the green triangles. The conclusion that the export-product mix changes more than the export-destination mix seems plausible and in accordance with the literature on export patterns.[7]

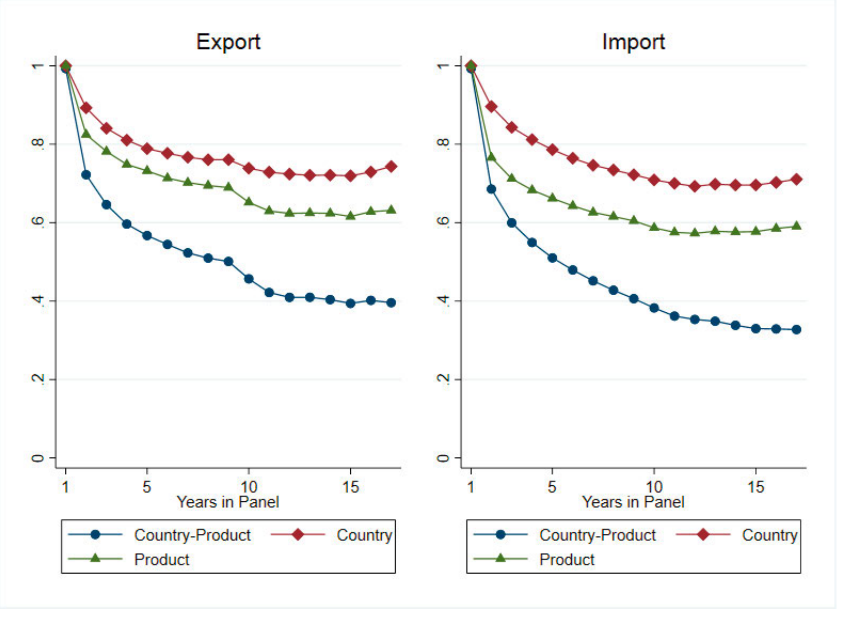

Figure 1. Mean firm-level trade weights

In the right panel in Figure 1, the mean firm-level import country-product weights (W^I_{jck}) line has a comparable shape to W^E_{jck} but is slightly steeper. In the final period, the original import country-product basket still corresponds to 37 percent of the total import value. Hence, the import weights are relevant to the firm even after 16 years. The red diamonds in the right panel show that the import-country mix reflects around 70 percent of the trade value after 16 years, and it stabilizes at that level after approximately ten years. The original import-product mix, illustrated by the green triangles in the right panel, drops to around 60 percent of the total trade value after seven years, and then stabilizes at that level throughout the studied period. The main insight from Figure 1 is that the initial export and import country-product weights seem persistent and still relevant to the firm many time periods later. The finding is important for the validity of the trade opportunity variables, as the trade expo-

[7] The drop in the export product and export country-product lines is due to a major change in export product code classifications around 2007 which the harmonization tables have not fully been able to account for. Even if firms are allowed to enter the panel at any year, a majority of the firms are in the sample through the studied period, making the product classification change visible in the data.

sure weights are used for the construction of the firm-level export demand and import supply variables.

2.5 Aggregation to the Firm Level

In sections 2.3 and 2.4 we investigated the validity of the country-product-year export demand and import supply variables, and the trade exposure weights. This section proceeds with the procedure of combining the ED_{ckt} and IS_{ckt} variables with the firm-level trade exposure weights W^E_{jck} and W^I_{jck} to get the export demand (ED_{jt}) and import supply (IS_{jt}) variables at the firm-year level. For each firm-year observation, the export demand variables are aggregated as follows:

$$ED_{jt} = \sum_{c,k} W^E_{jck} ED_{ckt} \tag{6}$$

where the firm-level export weights times the export demand variable at the country-product level in a given year are summed for each firm to generate ED_{jt}. Likewise, for each firm-year observation, the import supply variables are aggregated as follows:

$$IS_{jt} = \sum_{c,k} W^I_{jck} IS_{ckt} \tag{7}$$

where IS_{jt} is the firm-specific import supply variable.

2.6 Estimation Strategy

The trade opportunity variables, export demand and import supply, are arguably exogenous to firm-level decisions on firm growth, R&D investments, and innovations. A fixed-effects estimation strategy is employed to eliminate potential bias induced by any correlation between time-invariant firm-level characteristics and the levels of the trade-opportunity variables. Any remaining bias caused by such correlations will also disappear as the number of country-product shocks grows large (Borusyak et al., 2021; Goldsmith-Pinkham et al., 2020). The identifying assumption is that after controlling for sector-year and firm-level fixed effects, the variations in export demand and import supply are uncorrelated with other shocks to the firm growth, R&D, and innovation outcome variables. The fixed-effects regression model can be spelled out as follows:

$$Y_{jt} = \alpha + \beta ED_{jt} + \theta_j + I_k \times \tau_t + \varepsilon_{jt} \tag{8}$$

where Y_{jt} is the R&D or innovation outcome variable, ED_{jt} is the export demand trade-opportunity variable, θ_j represents the firm fixed effect, $I_k \times \tau_t$ are industry-year fixed effects, and ε_{jt} is the error term. For import supply, ED_{jt} in equation (8) is replaced by IS_{jt}.

Controlling for firm-level fixed effects should take care of the potential bias caused by the correlation between firm characteristics and future changes in the export demand or import supply variables. In addition to the firm-level fixed effects, the fixed-effects model specification includes industry-year fixed effects, where an industry is defined at the two-digit Swedish industry code level. These fixed effects will control for industry-year-specific shocks to productivity or trade that may influence the R&D investments or innovative activities of the firm. The estimation strategy described by equation (8) will be used throughout the paper, with some minor variations for robustness checks.[8]

2.7 Construction of Samples

In total, three different samples are constructed for the main analysis. The first sample contains all firms from the raw accounts data that have recorded both exports and imports in a given year, and is the largest sample with 368,006 firm-year observations. The second sample is the R&D sample with 8,475 firm-year observations and consists of all trading firms present in the R&D survey. The third and final sample is the innovation sample which builds on the trading firms included in the Community Innovation Survey. It contains 43,212 firm-year observations. To be included in any of the samples the firm needs to have recorded both exports and imports at some point in time. Otherwise, the firm is not assigned the export demand and import supply variables, and is thus not a part of any of the studied samples.

2.8 Descriptive Statistics

Summary statistics of the firm-level variables, the trade opportunities, and the R&D and innovation outcome variables are presented in Table 2. The mean value of each variable is displayed together with the associated standard deviation (in parenthesis). Table 2 points to some notable similarities and differences between the different samples. First, the mean values and standard deviations of the trade-opportunity variables, export demand and import supply, appear comparable across all three samples.[9] The mean export intensity, however, is strikingly larger in the R&D sample (42 percent) compared to the sample of all firms (11 percent). It is also slightly larger in the innovation sample (19 percent) compared to the sample of all firms. On the other hand, av-

[8]Tables A1, A2, and A3 in the appendix show results from alternative fixed effects specifications, where additional firm-level control variables are included.

[9]The correlation between export demand and import supply is 0.13.

Table 2. *Summary statistics by sample: mean values and standard deviations*

Sample:	(1) All Firms	(2) R&D	(3) Innovation
Firm characteristics			
Export Demand	0.03 (0.05)	0.04 (0.04)	0.03 (0.04)
Import Supply	0.06 (0.08)	0.06 (0.05)	0.05 (0.06)
Export Intensity	0.11 (0.20)	0.42 (0.32)	0.19 (0.27)
Import Intensity	0.16 (0.22)	0.15 (0.15)	0.13 (0.17)
Sales (log)	16.79 (1.75)	19.96 (1.65)	18.46 (1.68)
Value Added (log)	15.41 (1.79)	18.83 (1.56)	17.30 (1.56)
Employees (log)	2.42 (1.52)	5.30 (1.41)	4.01 (1.37)
High Educ. (log)	1.47 (1.38)	4.19 (1.40)	2.59 (1.61)
Ph.D. (log)	1.30 (1.35)	3.83 (1.43)	2.29 (1.61)
R&D outcomes			
R&D Expenses (log)		16.36 (1.84)	
R&D Intensity (R&D/Sales)		0.08 (0.14)	
R&D Employees (log)		2.40 (1.68)	
R&D Employees (share)		0.13 (0.17)	
Innovation outcomes			
Product Innovation			0.34 (0.47)
Process Innovation			0.33 (0.47)
Service Innovation			0.18 (0.39)
Observations	368,006	8,475	43,212

Notes: The table displays the mean values and the standard deviations (in parenthesis) of the firm characteristics, and of the R&D and innovation outcomes. Each column represents a different sample as indicated by the column header.

erage import intensities and accompanying standard deviations are more alike across the three samples.

Firms in both the R&D and innovation samples have higher average values of sales, value-added, and the number of employees compared to the sample of all firms. The survey sampling procedure, where the largest firms are always included in both the R&D survey and the CIS, is one reason for the differences in size compared to the sample of all firms. Another reason is that it is more likely that the largest and most productive firms can afford to do R&D and innovate compared to smaller and less productive firms.

In the R&D sample, the average log R&D expenditure is 16.36 (12.7 million SEK), and the average number of log sales is 19.96 (466 million SEK). This can be compared to the average log sales among all firms, which is 16.79 (19.5 million SEK). That is, the average R&D expenditure for firms in the R&D sample is approximately 65 percent of the average total sales for all firms, while the average total sales in the R&D sample is almost 24 times higher compared to the average sales in the sample of all firms. As a share of sales, the R&D expenditure is on average 8 percent, and the mean value of the share of R&D full-time equivalent employees is 13 percent.

As seen in column (3), the mean value for product innovation is 34 percent in the innovation sample. For process innovation, the corresponding number is 33 percent. The service-innovation mean value is slightly lower with an average across all firms of 18 percent. Taken together, it seems as product and process innovations are, on average, the most common types of innovations, and that service innovation occurs less frequently. Although the empirical strategy aims at controlling for differences between firms, and eliminating other potential threats to identification like reversed causality and omitted variable bias, we may still want to keep in mind the similarities and differences between the types of firms included in the three samples when we interpret the results presented in section 3.

3 Results

Through the empirical framework, we will now study the potential differential effects of export demand and import supply on firm-level growth, R&D investments, and innovation outcomes. First, the influence of trade opportunities on variables related to firm growth is studied. The investigation involves actual trade intensities, sales, value-added, the number of employees, and the number of high-skilled employees at the firm level.

3.1 Export and Import

Table 3. *Trade: Export and Import*

	Export		Import	
	(1) Export/Sales	(2) ln(Export)	(3) Import/Sales	(4) ln(Import)
Export Demand	0.074***	0.542**		
	(0.012)	(0.240)		
Import Supply			0.022***	0.494***
			(0.007)	(0.094)
Industry × Year FE	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Adj R^2	0.73	0.76	0.70	0.79
Observations	368,006	368,006	368,006	368,006

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

The first exercise provides insights into the relationship between trade opportunities and actual trade intensities and levels. In Table 3, we find the impact of export demand on export intensity, defined as export divided by sales (column (1)), and on the logarithm of exports (column (2)). If export demand rises by 1 percentage point, the export intensity of the firm would increase by approximately 0.07 percentage points, and export in levels by 0.6 percent. The findings indicate positive effects of improved export opportunities on exports in both intensity and levels. Similarly, columns (3) and (4) in Table 3 display positive effects of import opportunities on import intensity (imports divided by sales), as well as the level of imports. While the export value is a part of total sales, the import value is not. Therefore, dividing imports by sales is simply a way of creating a scaled version of imports that accounts for firm size. Column (3) shows imports also become a larger proportion of the firm size when the firm faces an opportunity to import cheaper inputs. A one percentage point higher import supply yields a rise in import intensity by around 0.02 percentage points, and imports in levels in column (4) by approximately 0.5 percent.

Table 4. *Trade: Products and Destinations*

	Export		Import	
	(1) ln(Products)	(2) ln(Destinations)	(3) ln(Products)	(4) ln(Destinations)
Export Demand	0.243**	0.161**		
	(0.114)	(0.088)		
Import Supply			0.262***	0.063
			(0.055)	(0.040)
Industry×Year FE	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Adj R^2	0.74	0.83	0.80	0.79
Observations	368,006	368,006	368,006	368,006

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table 4 shows the impact of changes in trade opportunities on the number of exported (imported) products and the number of export destinations (import origins). In columns (1) and (2) we find that improved export demand has a positive impact on both the number of exported products and the number of export destinations. In contrast, better opportunities to import intermediate inputs seem to lead to a significantly larger number of imported products, but there is no not significant expansion in the number of countries they source from. Taken together, the findings from Tables 3 and 4 show that trade opportunities affect actual trade at the firm level. The export demand variable has a positive and statistically significant impact on all measures of export. Positive shocks to import supply lead to larger import intensity, import value, and number of products imported.[10]

3.2 Firm Growth in Sales, Value-Added, and Employment

Table 5. *Sales, Value-Added, and Employment*

	(1) ln(Sales)	(2) ln(VA)	(3) ln(Emp)	(4) ln(HighEdu)	(5) ln(PhD)
Panel A. Export Demand					
Export Demand	0.288***	0.277***	0.123**	0.188***	0.173***
	(0.071)	(0.070)	(0.049)	(0.058)	(0.063)
Adj. R^2	0.93	0.90	0.92	0.90	0.90
Observations	368,006	368,006	368,006	368,006	368,006
Panel B. Import Supply					
Import Supply	0.171***	0.252***	0.085***	0.073**	0.047
	(0.034)	(0.034)	(0.025)	(0.029)	(0.032)
Adj. R^2	0.93	0.90	0.90	0.88	0.87
Observations	368,006	368,006	368,006	368,006	368,006
Industry×Year FE	yes	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes	yes

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

The impacts of trade opportunities on growth-related variables are shown in Tables 5. The result in column (1) in Panel A speaks directly to the effect of export demand on market size, given by firm sales. A one percentage point rise in export demand yields a 0.3 percent response in sales. The estimated effect is statistically significant at all conventional significance levels, and the implied change in firm-level sales also seems large and economically meaningful. In column (2), we find the result for value-added to be comparable to the finding for sales. With a one percentage point increase in export demand, the growth in value-added is 0.28 percent. Among the firm-level outcome variables investigated, both sales and value-added can be seen as variables that react more instantly to changes in trade opportunities compared to the slower processes of hiring or firing workers. Despite this, we see that the total number of employees goes up with better export opportunities (column (3)), and columns (4) and

[10] Akin to an instrumental variable setting, the results in Tables 3 and 4 could be viewed as first-stage results, speaking to the relevance of the instruments. But as stressed earlier, the export and import trade opportunity variables will not be used as instruments in this paper. Instead, the outcome variables will be regressed directly on the trade-opportunity variables, and consequently, we will be able to interpret the reduced form estimates in terms of changes in trade opportunity throughout the paper.

(5) show that both the number of highly educated employees and the number of employees holding a Ph.D. degree surge with a positive shock to export demand. Thus, firms seem to grow along numerous dimensions when facing possibilities to expand their markets. The fact that firms expand their workforce also in terms of highly-skilled workers suggests that the increased scale is not purely due to production workers. In a broad sense, it could be seen as a first indication of investments in activities related to R&D and innovations.

Panel B shows how changes in import supply impact firm-level outcomes. The estimated response in sales from a one percentage point increase in import supply is 0.17 percent. A similar boost in import supply generates an estimated change in value-added of 0.26 percent. In addition, there are responses in both the total number of employees and the number of highly educated workers to changes in import supply. Concluding that both export demand and import supply influence firm growth, we now turn to the effects of trade opportunities on the R&D investments and innovations of the firm.

3.3 Export Demand - R&D Investments and Innovations

Table 6 shows the estimated impact of export demand on R&D outcomes. The regression models include industry-year and firm fixed effects, implying that the estimated changes occur within the firm. Across the columns, I vary the R&D indicators used as outcomes, but all estimates are large, positive, and statistically significant. In column (1) we find a positive scale effect on total R&D expenditure. A change in export demand of one percentage point yields an estimated adjustment in total R&D spending of 3.5 percent. In column (2), a one percentage point improved export demand makes the R&D intensity of the firm, defined as R&D expenditure over sales, surge by 0.1 percentage points, although the estimate is not statistically significant. Moreover, export demand shows a positive impact on the log of R&D employees in column (3) and the ratio of R&D employees to all employees in column (4). A rise in export demand of one percentage point leads to an approximate increase in the number of R&D employees of 2.8 percent. The corresponding response in the intensity of R&D employees is 0.33 percentage points. These findings point to a similar conclusion as the findings for high-skilled and Ph.D. employees in Table 5; firms seem to invest in workers involved in R&D and innovative activities when facing market-expanding opportunities. Interestingly, not only the number of R&D employees, but also R&D employees as a share of total employees increases. To some degree, this shows that the firm expands its R&D activities more compared to its other activities. Next, we will investigate if this is also true for innovations.

How export opportunities affect product, process, and service innovation are displayed in Table 7. Column (1) shows a positive effect on product innovation; a one percentage point surge in export demand results in an estimated

Table 6. *R&D*

	(1) ln(R&D)	(2) R&D/Sales	(3) ln(R&D emp.)	(4) R&D emp./Emp.
Export Demand	3.473***	0.132	2.792***	0.330*
	(1.110)	(0.164)	(1.046)	(0.199)
Industry×Year FE	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Adj R^2	0.90	0.85	0.90	0.87
Observations	8,475	8,475	8,475	8,475

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

increased probability of product innovation by 0.3 percentage points. The positive effect of export demand is larger for process demand in column (2), and the probability of process innovation goes up by 0.4 percentage points if export demand rise by one percentage point. In the analysis of product and process innovation, it seems as if the two types of innovation react identically to changes in export opportunities. Better export opportunities increase the likelihood of variety expanding or quality upgrading product innovations, as well as cost-saving process innovations. In column (3), service innovation, defined as a new or quality upgraded service, seems to follow a similar pattern as product and process innovation. The estimated effect of export demand is positive and almost around the same magnitude as for product innovation, although it is not statistically significant at any conventional significance level. The pattern we saw for R&D in Table 6, with positive effects from export opportunities, also seems valid for innovations in Table 7.

Table 7. *Innovation*

	(1) Product	(2) Process	(3) Service
Export Demand	0.287*	0.441**	0.220
	(0.172)	(0.199)	(0.157)
Industry×Year FE	yes	yes	yes
Firm FE	yes	yes	yes
Adj R^2	0.64	0.51	0.55
Observations	43,212	43,212	43,212

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

3.4 Import Supply - R&D Investments and Innovations

Improved export opportunities generate more R&D investments and innovations. Now we turn to import opportunities to find out if they have a similar or differential effect. As displayed in Table 8, better opportunities to import seem to have a positive impact on all R&D variables, although none is statistically significant. Comparing the size of estimates to the results in Table 6 where export demand is considered, they are much smaller across all R&D outcomes, indicating that shocks to import supply matter less when the firm decides on R&D investments. The estimates in Table 8 are only between one-tenth to one-third the size of the estimated effects in Table 6. That is, price cuts of inputs do not seem to be as big of an incentive to invest in R&D as the possibility to reach a larger market.

Table 8. *R&D*

	(1) ln(R&D)	(2) R&D/Sales	(3) ln(R&D emp.)	(4) R&D emp./Emp.
Import Supply	0.415 (0.663)	0.038 (0.089)	0.934 (0.680)	0.060 (0.102)
Industry×Year FE	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Adj R^2	0.90	0.85	0.90	0.87
Observations	8,475	8,475	8,475	8,475

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

In contrast to the insignificant but still positive estimates on R&D from improved import opportunities, the impact on innovation is negative and statistically significant. As is clear from Table 9, it seems as better opportunities to import lead to a substitution effect where the firm's in-house innovation is partly substituted by cheaper, or higher-quality, imports. A positive import supply shock indicates a decreased probability of product, process, and service innovation. If import opportunities increase by one percentage point the probability of a product innovation falls by approximately 0.19 percentage points, and process innovation by 0.21 percentage points. For service innovation, a one percentage point rise in import supply yields a 0.24 percentage point decrease in the probability of service innovation. These results are in stark contrast to the findings for export demand in Table 7. Now that we have established the differential instantaneous effects on innovation from export demand and import supply, the next section will explore if there are some lagged effects of trade opportunities on R&D investments and innovations.[11]

[11] See Appendix Tables A4 and A5 for results from regression models where both export demand and import supply are included in the same model.

Table 9. *Innovation*

	(1) Product	(2) Process	(3) Service
Import Supply	-0.187*	-0.210*	-0.239***
	(0.099)	(0.115)	(0.091)
Industry×Year FE	yes	yes	yes
Firm FE	yes	yes	yes
Adj R^2	0.64	0.51	0.55
Observations	43,212	43,212	43,212

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

3.5 Lagged Effects

To investigate the possibility that the trade opportunities faced by the firm today may influence future R&D and innovations, I estimate models with one-year lagged trade-opportunity variables. Table 10 displays the results from regressing the R&D outcomes on lagged export demand. Comparing the estimated effects of lagged export demand on the R&D outcomes in Table 10 to the main results in Table 6, we can conclude that the effects do not seem to be larger the year after the export opportunity shock, but rather around the same magnitude for ln(R&D) in column (1) and both of the R&D employee outcomes in columns (3) and (4). On the other hand, the estimate of lagged export demand on the R&D expenditure over total sales is about half the size compared to the instantaneous effect, but not statistically significant.

Table 10. *R&D - One year lagged Export Demand*

	(1) ln(R&D)	(2) R&D/Sales	(3) ln(R&D emp.)	(4) R&D emp./Emp.
Export Demand [t-1]	3.225***	0.024	2.428***	0.211***
	(0.744)	(0.074)	(0.695)	(0.083)
Industry×Year FE	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Adj R^2	0.91	0.85	0.90	0.87
Observations	8,345	8,345	8,345	8,345

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Similarly, Table 11 shows the results for the innovation outcomes when export demand is lagged by one year. For innovations, in particular, there may be reasons to believe a trade-opportunity shock today may influence the outcomes even further ahead in time. For example, Aghion et al. (2022) find the largest effects of a market size enlargement today on patents two to five years ahead in time. We should, however, note that the innovation variables in this paper are not patents but self-reported innovations by the firm. The patent application processes have longer built-in time lags that do not apply to the self-reported innovation variables employed here. Moreover, the short panel structure combined with the innovation survey spanning multiple time periods further limits the possibility of a more thorough investigation of the long-term impact on innovation. The estimates of lagged export demand on the innovation outcomes are slightly closer to zero here compared to the estimates in Table 7, but still indicate positive effects. However, none of the estimates are statistically significant at any conventional significance level when the previous year's export demand is considered.[12]

Table 11. *Innovation - One year lagged Export Demand*

	(1) Product	(2) Process	(3) Service
Export Demand [t-1]	0.213	0.287	0.023
	(0.166)	(0.192)	(0.151)
Industry×Year FE	yes	yes	yes
Firm FE	yes	yes	yes
Adj R^2	0.64	0.51	0.56
Observations	41,724	41,724	41,724

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

As seen in Table 12, the estimated effects of lagged import supply on the R&D outcomes are smaller compared to the results in Table 8, and still not statistically significant. The lack of statistical significance for both the instantaneous and lagged effect makes it hard to draw any clear conclusions about the impact of import supply on R&D. For the innovation outcomes in Table 13, the coefficients of lagged import supply are comparable to the results found in Table 9. The estimates are also statistically significant at the 10 percent level for product innovation, and at the 5 percent level for process and service innovation. The findings indicate there may be effects on innovation in the future from changes in trade opportunities today.[13]

[12] Tables A6 and A7 in the Appendix show models including both the instant and lagged effects. These tables underline that the instant effects are larger than the lagged effects.

[13] Also for import supply, Tables A8 and A9 in the Appendix including models with both instant and lagged effects show that the instant effects are larger than the lagged effects. Furthermore, they show that a positive shock to import supply last year may even have a negative influence on R&D investments today.

Table 12. *R&D - One year lagged Import Supply*

	(1) ln(R&D)	(2) R&D/Sales	(3) ln(R&D emp.)	(4) R&D emp./Emp.
Import Supply [t-1]	0.076	0.037	0.376	-0.017
	(0.453)	(0.045)	(0.422)	(0.050)
Industry×Year FE	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Adj R^2	0.90	0.85	0.90	0.87
Observations	8,345	8,345	8,345	8,345

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table 13. *Innovation - One year lagged Import Supply*

	(1) Product	(2) Process	(3) Service
Import Supply [t-1]	-0.180*	-0.272**	-0.217**
	(0.094)	(0.108)	(0.085)
Industry×Year FE	yes	yes	yes
Firm FE	yes	yes	yes
Adj R^2	0.64	0.51	0.56
Observations	41,724	41,724	41,724

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

4 Conclusions

This paper investigates the effects of firm-specific export and import opportunities on R&D and innovation - two key variables we know contribute to economic growth and welfare. The trade-opportunity variables - export demand and import supply - are constructed from the firm's initial exporting and sourcing patterns, combined with how exposed this makes them to changes in international trade flows. Hence, the trade-opportunity variables ensure a direction of causality from trade to R&D and innovation, and are tested in multiple ways. Through these exercises, the firm-specific exporting and sourcing patterns are shown to be persistent and still reflect around 40 percent (37 percent) of the total export (import) value after 16 years. In addition, granular regressions at the country-product-year level show clear effects on trade volumes; an indication that the export demand and import supply variables reflect changes in trade relevant to the firm.

The analysis built on detailed Swedish register data covering the period 1997-2014 shows that both export and import opportunities have positive impacts on firm growth, measured as sales, value-added, employees, and high-skilled employees. Firm-level export and import also react as anticipated, with strong responses in exports from export opportunities, and imports from import opportunities. Changes in export demand and import supply do, however, seem to have differential impacts on firm-level R&D investments and innovations. Improved export demand generates growth in R&D spending and R&D employees, and also shows positive impacts on product, process, and service innovation. The findings indicate that market-expanding opportunities lead to more investments in R&D and innovation - results in line with suggestions from earlier literature. On the other hand, import opportunities do not seem to significantly affect R&D spending. The estimated effects are only about one-tenth of the effects of export demand and not statistically significant. Moreover, import supply shows negative effects on product, process, and service innovation revealing the possibility that firms view outsourcing as a substitute for their own innovation.

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Appendix A Figures and Tables

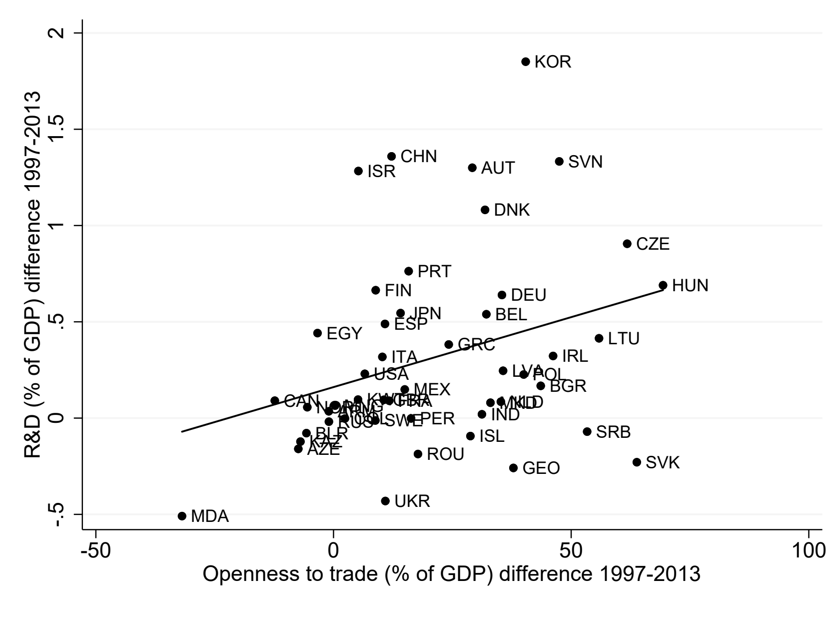

Figure A1. Country-level changes in openness to trade and changes in R&D (1997-2013). *Notes:* Figure A1 shows a positive correlation between country-level changes in R&D spending and changes in openness to trade during the period studied in this paper (1997-2013). Countries that increased their openness to trade during this period also seem to have increased their R&D spending.

Table A1. *R&D - Alternative fixed effects*

	(1) ln(R&D)	(2) ln(R&D)	(3) ln(R&D)	(4) ln(R&D)	(5) ln(R&D)	(6) ln(R&D)
Export Demand	4.009***	2.094***	2.576***			
	(0.328)	(0.296)	(0.699)			
Import Supply				2.693***	1.138***	0.581
				(0.288)	(0.255)	(0.436)
ln(Sales)	0.114**	0.250***	0.196***	0.133***	0.266***	0.199***
	(0.044)	(0.043)	(0.049)	(0.045)	(0.043)	(0.049)
ln(VA)	-0.058	-0.043	-0.080***	-0.075*	-0.050	-0.078***
	(0.045)	(0.040)	(0.028)	(0.045)	(0.040)	(0.029)
ln(Emp)	0.734***	0.758***	0.574***	0.728***	0.748***	0.575***
	(0.056)	(0.052)	(0.054)	(0.056)	(0.052)	(0.054)
ln(Wage)	3.213***	2.396***	0.364***	3.199***	2.394***	0.363***
	(0.069)	(0.069)	(0.063)	(0.070)	(0.069)	(0.063)
Sales/Worker	-0.000**	-0.000**	0.000	-0.000***	-0.000***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
VA/Worker	0.000	0.000***	0.000**	0.000*	0.000***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year FE	yes	no	no	yes	no	no
Industry×Year FE	no	yes	yes	no	yes	yes
Firm FE	no	no	yes	no	no	yes
Observations	8,475	8,475	8,475	8,475	8,475	8,475

Notes: Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A2. *Export Demand: Process and Product - Alternative fixed effects*

	(1) Product	(2) Product	(3) Product	(4) Process	(5) Process	(6) Process
Export Demand	0.392***	0.191***	0.286*	0.173***	0.044	0.437**
	(0.055)	(0.053)	(0.172)	(0.054)	(0.055)	(0.199)
ln(Sales)	0.010***	0.008**	0.000	-0.019***	0.004	0.006
	(0.004)	(0.004)	(0.007)	(0.004)	(0.004)	(0.008)
ln(VA)	0.020***	0.036***	0.002	0.028***	0.015**	-0.003
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
ln(Emp)	0.008	0.002	0.010	0.055***	0.049***	0.039***
	(0.006)	(0.006)	(0.009)	(0.006)	(0.006)	(0.010)
ln(Wage)	0.070***	0.092***	0.017	0.006	0.012	0.039***
	(0.009)	(0.010)	(0.011)	(0.009)	(0.010)	(0.013)
Sales/Worker	-0.000***	-0.000**	0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
VA/Worker	-0.000***	-0.000***	0.000	-0.000	-0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year FE	yes	no	no	yes	no	no
Industry×Year FE	no	yes	yes	no	yes	yes
Firm FE	no	no	yes	no	no	yes
Observations	43,212	43,212	43,212	43,212	43,212	43,212

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A3. *Import Supply: Process and Product - Alternative fixed effects*

	(1) Product	(2) Product	(3) Product	(4) Process	(5) Process	(6) Process
Import Supply	0.249***	0.036	-0.183*	0.064*	0.025	-0.194*
	(0.037)	(0.036)	(0.099)	(0.036)	(0.037)	(0.115)
ln(Sales)	0.008**	0.008*	0.000	-0.020***	0.004	0.006
	(0.004)	(0.004)	(0.007)	(0.004)	(0.004)	(0.008)
ln(VA)	0.021***	0.036***	0.003	0.028***	0.015**	-0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
ln(Emp)	0.010*	0.003	0.010	0.056***	0.049***	0.039***
	(0.006)	(0.006)	(0.009)	(0.006)	(0.006)	(0.010)
ln(Wage)	0.072***	0.093***	0.016	0.007	0.012	0.039***
	(0.009)	(0.010)	(0.011)	(0.009)	(0.010)	(0.013)
Sales/Worker	-0.000***	-0.000**	0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
VA/Worker	-0.000***	-0.000***	0.000	-0.000	-0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year FE	yes	no	no	yes	no	no
Industry×Year FE	no	yes	yes	no	yes	yes
Firm FE	no	no	yes	no	no	yes
Observations	43,212	43,212	43,212	43,212	43,212	43,212

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A4. *R&D*

	(1) ln(R&D)	(2) R&D/Sales	(3) ln(R&D emp.)	(4) R&D emp./Émp.
Export Demand	2.557***	0.195***	1.900***	0.327***
	(0.700)	(0.068)	(0.655)	(0.079)
Import Supply	0.546	0.044	1.059***	0.045
	(0.436)	(0.043)	(0.408)	(0.049)
Industry×Year FE	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Adj R^2	0.91	0.86	0.91	0.87
Observations	8,475	8,475	8,475	8,475

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A5. *Innovation*

	(1) Product	(2) Process	(3) Service
Export Demand	0.294*	0.445**	0.226
	(0.172)	(0.199)	(0.157)
Import Supply	-0.187*	-0.200*	-0.238***
	(0.099)	(0.115)	(0.091)
Industry×Year FE	yes	yes	yes
Firm FE	yes	yes	yes
Adj R^2	0.64	0.51	0.56
Observations	43,212	43,212	43,212

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A6. *R&D - One year lagged Export Demand*

	(1) ln(R&D)	(2) R&D/Sales	(3) ln(R&D emp.)	(4) R&D emp./Emp.
Export Demand	2.793***	0.147	2.519***	0.173*
	(0.944)	(0.094)	(0.882)	(0.104)
Export Demand [t-1]	1.474	-0.068	0.849	0.102
	(0.951)	(0.094)	(0.888)	(0.105)
Industry×Year FE	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Adj R^2	0.91	0.85	0.90	0.87
Observations	8,345	8,345	8,345	8,345

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A7. *Innovation - One year lagged Export Demand*

	(1) Product	(2) Process	(3) Service
Export Demand	0.148	0.297	0.418**
	(0.221)	(0.255)	(0.201)
Export Demand [t-1]	0.130	0.121	-0.211
	(0.207)	(0.239)	(0.188)
Industry×Year FE	yes	yes	yes
Firm FE	yes	yes	yes
Adj R^2	0.64	0.51	0.56
Observations	41,724	41,724	41,724

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A8. *R&D - One year lagged Import Supply*

	(1) ln(R&D)	(2) R&D/Sales	(3) ln(R&D emp.)	(4) R&D emp./Emp.
Import Supply	0.604	0.056	1.362**	0.152**
	(0.668)	(0.066)	(0.623)	(0.074)
Import Supply [t-1]	-0.318	0.000	-0.512	-0.116*
	(0.628)	(0.063)	(0.586)	(0.070)
Industry×Year FE	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes
Adj R^2	0.90	0.85	0.90	0.87
Observations	8,345	8,345	8,345	8,345

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Table A9. *Innovation - One year lagged Import Supply*

	(1) Product	(2) Process	(3) Service
Import Supply	-0.123	-0.088	-0.148
	(0.136)	(0.157)	(0.124)
Import Supply [t-1]	-0.104	-0.217	-0.125
	(0.126)	(0.146)	(0.115)
Industry×Year FE	yes	yes	yes
Firm FE	yes	yes	yes
Adj R^2	0.64	0.51	0.56
Observations	41,724	41,724	41,724

Notes: The dependent variables are indicated in column headers. Robust standard errors clustered at the firm level are in parentheses. Significance levels: *** ($p < 0.01$), ** ($p < 0.05$), and * ($p < 0.1$).

Essay IV. Regional differences in effects of publicly sponsored R&D grants on SME performance

Co-authored with Patrik Tingvall

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Regional differences in effects of publicly sponsored R&D grants on SME performance

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Abstract This paper explores regional variation in the effects of publicly sponsored R&D grants on SME performance. The results suggest that there is no guarantee that the grants will impact firm growth, either positive or negative. Positive growth effects are most likely to be found for publicly sponsored R&D grants targeting SMEs located in regions abundant with skilled labor, whereas the opposite is found for SMEs located in regions with a limited supply of skilled labor.

Keywords R&D grants · SME · Economic growth · Regional growth · Selective policies

JEL classification H81 · O38 · O40 · R11 · R58 · L26

1 Introduction

The importance of innovation as a key driver of long-run economic growth is well established. However, although the link between innovation and growth is recognized, there is no consensus regarding the best policy through which to achieve innovation and growth. Interestingly, Veugelers (2015) shows that innovation policies deployed in EU member states seem, to a great extent, to apply similar combinations of instruments, regardless of their innovation capacity. In this vein, direct R&D grants and support through tax incentives are two commonly applied measures. Sweden, however, is somewhat of an outlier in this area, as it has a strong focus on direct government funding through R&D grants and a low reliance on R&D tax-incentives (OECD, Organization for Economic Co-operation and Development 2015a).

Apart from having innovation and growth as desired outcomes, many growth-oriented government programs tend to focus their efforts on supporting small- and medium-sized enterprises (SMEs). New ventures and innovative SMEs account for a large share of net job-creation and productivity growth. These capabilities are well documented, but due to a lack of financial resources or competitive elements in the industry, many new firms are not able to survive their first year(s) of business (Shane 2009; Nightingale and Coad 2014). As a response to these complications, governments have—in the last couple of decades—been implementing various policies that aim to increase SME survival rates and innovation. One channel through which governments support private enterprises is via "targeted R&D grants." However, even though there is a history of targeted R&D grants, surprisingly little is known about the actual effects of such policies (Edler et al. 2013).[1]

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[1] The relative richness of micro-level data and strong focus on grants rather than R&D subventions makes Sweden a proper instrument for analyzing growth effects from publicly sponsored innovation targeted grants.

In summarizing studies that analyze the impact of various R&D grants and subventions, it is clear that results vary. Bronzini and Iachini (2014) assessed the effects of receiving an investment grant on R&D in northern Italy. They found that such grants had positive effects on R&D for small enterprises, whereas large companies did not seem to be affected by the grants. Cin et al. (2017) found R&D subsidies to enhance the performance of Korean SMEs. For Finland, Koski and Pajarinen (2013) showed that R&D support seemed to lead to an increase in the number of employees as long as support was given to the firm, but these results did not persist after the funding ended. Similar results with a lack of long-lasting effects were also found by Cappelen et al. (2016) for Norway. Zúñiga-Vicente et al. (2014) summarize the results of 77 studies on different R&D support schemes. They uncovered three fairly stable patters: (i) The amount of crowding-out is closely related to the financial restrictions facing the companies, (ii) the growth effects vary across basic- and applied research, and (iii) the impact of a grant is larger for smaller firms. The finding that the impact of a grant seems to be largest for smaller firms is further supported by Gonzalez et al. (2005), Criscuolo et al. (2012), Heshmati and Lööf (2005), and Gustafsson et al. (2016). There are also indications of start-ups being more innovative than established firms (Acs and Audretsch 1988).

One area in which there seems to be a relative large lack of knowledge is connected to the regional dimension. In some regions, innovation and growth targeted programs may work better than in others. It is well-established that finding skilled labor can be both problematic and a factor limiting growth among many innovative and R&D-intensive firms (for an international outlook on this matter see Rutkowski (2007) and OECD, Organization for Economic Co-operation and Development (2015b), and for Sweden see Tillväxtverket (2011)). It has also been shown that the most important factor determining firms' localization decision is access to qualified workers (UNCTAD 1997).

Hence, the local supply of skilled labor can be seen as a critical factor for the growth prospect of innovative and R&D-intensive firms, and we cannot exclude the possibility that the impact of innovation grants will be dependent on the local supply of skilled labor. Our question is, therefore, are there any regional differences in the growth effects of publicly sponsored innovation and growth targeting grants, and what role does human capital have?

A few studies have taken a regional perspective on how subsidies impact firm performance. Banno et al. (2013) and Herrera and Nieto (2008) both found that R&D subsidies had stronger growth effects in central regions than in remote regions. Similar results were found by Piekkola (2007), whereas Doloreux (2004), in a Canadian study, did not find evidence for a significant difference across regions. Overall, these results suggest that regional characteristics matter for the impact of R&D subsidies, but the source of the heterogeneity remains unknown.

We contribute to this literature by explicitly focusing on the role of the local supply of human capital in shaping the impact of R&D grants. This route is motivated by the close link between innovation and human capital, as well as by a lack of knowledge of the role of the regional dimension in this area. Using information on the size of the grants combined with detailed firm and individual characteristics, we analyze the link between R&D grants and regional characteristics. From a policy and efficiency perspective, the regional dimension may be critical in order to understand the outcome of an intervention.

A main result of this study is that, in most cases, the R&D grants have no significant impact on firm growth, though the likelihood of finding a positive effect increases as the regional supply of skilled labor increases. Hence, the results suggest a positive connection between growth effects of the R&D grants and the regional supply of skilled labor.

The remainder of this paper is organized as follows. Section 2 discusses the background. Section 3 surveys empirical studies on the impact of innovation grants and subsidies with a focus on the regional dimension. Section 4 provides information about data and matching. The models are described in Sect. 5, and the results are outlined in Sect. 6. Finally, Sect. 7 summarizes the paper.

2 Background

There is a well-funded belief of innovation and R&D as a driver of long run economic growth (Schumpeter 1911; Solow 1957; Romer 1986; Lucas 1988; Aghion and Howitt 1998). The view of R&D as the solution to many pressing challenges spurred the development of innovation policies, wherein public R&D subsidies and grants constitute an important part of the package

(OECD, Organization for Economic Co-operation and Development 2015a). One central aspect of R&D is its close connection to knowledge spillovers and its dependency of skilled labor (Akerlof 1970; Stiglitz and Weiss 1981).

As early as in the beginning of the twentieth century, Marshall (1920) argued for three factors affecting the localization decision of a firm. In short, Marshall argued for (i) access to labor and a reasonable maximum commuting distance for workers, (ii) input and output links, and (iii) spillovers that are "in the air." The first argument is related to both the size of the local labor market and its content. What type of labor is accessible? It is well known that the comparative advantage of a region depends on the regional supply of production factors. In regard to innovation and R&D, local access to a well-educated labor force is instrumental (Dosi 1988; Feldman 1994a; Fujita et al. 1999), suggesting that the geographical distribution of innovative activities is interdependent with the distribution of skilled labor. The close connection between the prospects of successful R&D and the local supply of skilled labor is further supported by questionnaires, where the typical result is that one of the most important factors determining firms' localization decisions is access to qualified workers (UNCTAD 1997).

The importance of the local environment is further strengthened when we consider the influence of input-output linkages. Today, the interplay between input-output linkages, transportation costs, and scale effects, as vehicles for clustering and agglomeration, is formalized in the new economic geography (Fujita et al. 1999; Krugman 1991). Innovative firms are dependent on new knowledge, and most knowledge has a geographical dimension that makes it easier to transport between individuals and firms who are physically close. Dosi (1988) presents "five stylized facts" that help explain why knowledge spillovers are geographically bounded. Dosi's arguments have been further developed by Feldman (1994a, b) and Baptista and Swann (1998). Marjolein (2000) contributes to this literature with both theoretical arguments and an empirical overview regarding the local nature of knowledge. Hence, it is widely accepted that knowledge will spread, whether the owner wants it to or not, and that geographical closeness eases knowledge transfers. In summary, this branch of literature suggests that firms in knowledge-intensive industries benefit from a locally abundant supply of skilled labor and from the spillovers effects associated with innovative activities.

The system approach provides us with an additional explanation of why regions matter for innovation. This line of thinking stresses the importance of cooperation and of links between industry, government, and academia. Today, we lack an exact and commonly agreed upon definition of what a regional innovation system really is, but it can be said to be a collection of organizations, institutions, firms, and individuals among whom the creation, use, and distribution of new knowledge occur (Cooke 2004). Regardless of which definition we choose, the regional innovation system comprises all clusters of firms, as well as the institutional structures and rules that surround them. Within the system perspective, several arguments can be found to support the use of an active innovation policy (Asheim et al. 2011; Asheim and Gertler 2006; Cooke 2001; Cooke 2004; Doloreux and Parto 2005; Tödtling and Trippl 2005). A key component here is the central role played by skilled labor. That is, for innovation to take place, access to skilled labor is essential. Given this, surprisingly few studies have analyzed the relation between the outcome of selective R&D incentives and the local supply of skilled labor.

With the system perspective in mind, it becomes relevant to discuss possible interaction effects between the impact and efficiency of innovation grants and the local environment. We suggest that the likelihood that a R&D grant will generate positive growth effects is positively correlated with the local pool of skilled labor. That is, a larger local pool of skilled labor increases the possibility of finding the skills required by the firm, and also increases the related spillover effects.[2] To determine whether this suggestion is supported by real-world data, we will in subsequent chapters perform a difference-in-differences analysis in order to analyze the linkages between the growth effects of R&D grants and the relative size of the local labor pool that has tertiary education. One may note that while agglomeration factors generate clustering of skilled labor we do not intend to analyze drivers of agglomeration but rather take the local supply of skilled labor as given.[3]

[2] That is, we take the local supply of skilled labor as given. To change the local supply of skilled labor is a question more connected to education policies than the allocation of public R&D grants targeting SMEs.

[3] The reason for this approach is that when allocating grants, the local industrial structure can be seen as predetermined and externally given.

3 Empirical studies with a regional focus

The aim of this study is to, with special attention to the local supply of human capital, determine whether the effects of innovation grants differ among regions. Even though the role of the local supply of human capital has not been in focus in the mass of previous studies on innovation subsidies, regional variation per se has been studied in a series of papers, suggesting a number of interesting observations. To be precise, there are two sets of studies with a regional focus, one larger set dealing with regional grants which often has investment and employment in focus rather than innovation, and one smaller set of papers with a regional innovation focus. We hope to contribute to the latter.

In an influential paper, Baptista and Swann (1998) show that firms located in strong clusters tend to innovate more, where the strength of a cluster is measured in own-sector employment. Moreover, there is a number of studies indicating that the quality of the regional innovation system affects both the probability of innovation within firms and knowledge transfers across firms (Asheim et al. 2011; Cooke 2004; Doloreux and Parto 2005; Tödtling and Trippl 2005; Srholec 2010). This line of reasoning is consistent with the finding that in Finland, half of all R&D is conducted in the capital city, Helsinki, and that four regions are responsible for almost 80% of all R&D in Finland. A similar pattern holds true for the USA, where ten areas contribute to two thirds of all R&D activity in the country (Georghiou et al. 2003). It is, therefore, interesting to note that just as R&D activities, innovation subsidies and grants are not distributed evenly across regions. The probability of receiving innovation support is larger for a firm located in a central area compared to a peripheral area (Czarnitzki and Fier 2002; Gonzalez et al. 2005; Herrera and Nieto 2008). Moreover, based on the argument that technology is path-dependent, evolutionary economic geographers argue that the pre-existing routines and competences of institutions, firms, and labor in well-developed regions determine what kind of innovations they generate (Boschma and Martin 2007). In addition to this, the probability that a new industry enters a region increases with the number of pre-existing related industries in the region (Hidalgo et al. 2007; Neffke et al. 2011; Boschma et al. 2013; Boschma et al. 2015).[4]

A limited number of studies have investigated regional variations in the effects of innovation subsidies. For Italy, Banno et al. (2013) find that policies intended to stimulate R&D generate larger economic profits in regions that are relatively more internationalized than in remote regions. Similarly, Herrera and Nieto (2008) divide Spain into central and peripheral regions. Their analysis shows that the effects of R&D subsidies are larger in two out of three central regions compared to the rest of the country. Focusing on the importance of knowledge capital, Piekkola (2007) finds that growth from R&D subsidies is concentrated in regions that have a high level of knowledge capital to begin with.

Although it may seem like regions have a vital impact on the innovative activities of firms, some studies argue against this. One such example is Doloreux (2004), who conducts telephone interviews with small- and medium-sized Canadian firms. The results indicate that the R&D patterns within firms are the same across several Canadian regions. Moreover, most firms stated that they use national and global knowledge sources when innovating, and they downplayed the importance of the regional structure. Isaksen and Onsager (2010) reach a similar conclusion in their study of Norway, where they find that rural areas and smaller cities have a larger proportion of innovating firms compared to larger cities. This finding contradicts earlier research in this field. To explain their results, Isaksen and Onsager (2010) stress that innovation subsidies in Norway are aimed at firms in smaller cities and rural areas, as a part of Norway's overarching policy to develop the whole country. The over-representation of targeted firm located in remote regions is therefore likely to be driven by political decisions.

In short, most empirical evidence indicates that there are differences in regard to the distribution and the effects of R&D subsidies and grants. This suggests that there are reasons to take location into consideration when forming policies around the distribution of selective public R&D subsidies and grants.

4 Data and matching

4.1 Data

Firm level data on public grants and subsidies in Sweden is collected and stored in the MISS database by the Swedish Agency for Growth Policy Analysis. The

[4] The underlying drivers causing agglomeration of industries are fruitfully discussed in Ellison et al. (2010) and Glaeser (2008).

MISS database comprises information about the grant distributor and receiver, the size of the grant, and when the firm receives the payments. We link these data with yearly register data provided by Statistics Sweden (SCB) containing information on firms' input and output, covering all firms in the economy. Hence, information about both the treated and the non-treated firms is collected from these sources.

In addition to firm level data, individual level data on workers' education, wages, gender, and age is aggregated to the firm level and linked to firm data. Firm level and aggregated individual level data contains information on production, sales, employment, value added, investments, physical capital, profits, industry affiliation, educational attainment of the labor force, geographic location, etc., spanning the period 1997–2011. All datasets are linked using unique individual firm-year ID codes.

Out of the two analyzed programs "Win Now" and "Research & Growth," Win Now is the smaller program directed at start-ups (firms younger than 1 year at the time of application), and its funds can be granted to SMEs that have developed a new product, method, or service that has not yet reached the market. The aim is to give start-ups a chance to survive in the market by providing financial aid during the commercialization process, which is intended to attract external capital and make the business successful in the future. Hence, future growth is one of the main purposes of the grant. However, the timeframe for achieving growth is not specified. Half of the granted amount should be allocated to business development, while the other half can be used for R&D activities. A total of 1309 firms applied for Win Now, and approximately 10% received support. Win Now has been granted 125 times during the period under study (2002–2010), and the average grant was 164,847 SEK ($18,458). A firm is only granted the subsidy once, and the maximum amount awarded is 300,000 SEK ($33,592). Win Now can also be seen as a springboard to its sister program Research & Growth, targeting slightly older firms.[5]

The subsidy program Research & Growth targets small- and medium-sized innovative firms supporting developing projects, but support may also be awarded to pilot studies. Approximately 20% of the applicants were granted support, and the recipients consist mostly of SMEs that are already on the market. The purpose of Research & Growth is to support and promote innovation-driven growth within the subsidized firms. In all, the program provided 546 grants during the studied period (2005–2010), with an average grant of 543,321 SEK ($60,836). The project time is normally between 6 and 18 months.

Earlier empirical studies of the two programs Win Now and Research & Growth have produced mixed results. Some studies have found that they yield growth in employment and sales, while others have found negative outcome in, for example, employment, and productivity (Söderblom et al. 2015; Daunfeldt et al. 2016; Vinnova 2014). The different outcomes in these studies may be due to differences in empirical strategy, discussed in Daunfeldt et al. (2016).

The innovation grants analyzed here are distributed to firms in cities as well as rural areas. In Table 1, all Swedish regions and municipalities are divided into three different groups: *Big Cities*, *Support Areas A&B*, and *Other Areas*. This division is only used to provide an overview of the regional division of the grant sums. When carrying out the empirical analysis, the regions considered are the 60 Swedish functional labor market regions. The idea with the functional labor market regions is that most of the home-to-work commuting takes place within the region rather than across the borders. In addition, the labor market region should not be larger than it should be possible to, on a daily basis, commute between any two points within the region. For descriptive purposes, we choose to characterize Sweden in three dimensions, from dense city regions to rural areas. The first category, *Big Cities*, contains the three largest cities in Sweden: Stockholm, Gothenburg, and Malmo. The second category, *Support Areas A&B*, includes particularly vulnerable regions in Sweden. Vulnerable areas are those that have the right to apply for regional support.[6] The third and final group, *Other Areas*, comprises the remaining in-between regions in Sweden.

[5] The strategic package relation between "Win Now" and "Research & Growth" is one reason for why these programs are jointly evaluated. In addition, these programs have also been analyzed, jointly as well as individually in Daunfeldt et al. (2016) suggesting that they to some extent can be seen as a package. Finally, at the time for this analysis, these programs were probably the most innovation and growth focused public support programs in Sweden.

[6] For information on the Swedish regions eligible to apply for regional support, see: http://www.tillvaxtverket.se.

Table 1 Total and average grant sums, by group of regions

	Number of grants	Total sum	Average sum	Sum/employee
Big cities	218	215,000,000	986,830	36.22
Support areas A&B	45	22,800,000	506,648	11.75
Other areas	358	288,000,000	803,490	23.89
Total: Sweden	621	525,800,000	846,340	26.38

Note: In the empirical analysis, 60 labor market regions are utilized

As seen in Table 1, both the size of the average grant and funding per employee is largest in the *Big Cities*. There is a tendency to give more grants to firms in large cities compared to other firms, which is consistent with the internationally observed pattern regarding the distribution of R&D grants.

As noted above, the supply of skilled workers is a key component of innovation and growth. To measure the regional supply of high-skilled labor empirically, we construct a regional index. This index-variable is constructed as a revealed comparative advantage index (RCA-index), where a value above one indicates that a region is above the country average and vice versa. To simplify the interpretation of our regression variables, this index will be centered around zero in our analysis, and thus, a value above (below) zero will indicate that a region is above (below) the country average.[7] The measure of the relative supply of high-skilled labor is as follows:

$$RCA\text{-}Skill = \left(\frac{L_r^H}{L_r}\right) / \left(\frac{L_{Swe}^H}{L_{Swe}}\right) \quad (1)$$

where the first term describes the share of high-skilled labor in the region, and the second term describes the share of high-skilled labor in the country. The use of RCA-indices is common within the international trade literature, starting with Balassa (1965). In our setting, we might note that the RCA-index captures the relative concentration of skilled labor rather than factors behind this clustering. That is, from the governmental project coordinator perspective, when allocating grants, the spatial distribution of firms and human capital is taken as given.[8]

Table 2 reveals a clear picture of the distribution of skilled labor across regions in Sweden: skilled labor is concentrated in the large cities, whereas the opposite is true for the (rural) areas granted regional support measures. The RCA-index (based on 60 labor market regions) and firm level variables, sources, mean values, and standard deviations are described in Table 3.

4.2 Matching

As noted above, the R&D grants have both a specific purpose and are targeting a specific population of firms; hence, grants are not randomly distributed across firms. This, in turn, leads to the question of how to create a control group of similar firms. To handle this selection problem, we use coarsened exact matching (CEM) to create a control group of non-treated firms that, in all relevant aspects, are as similar as possible to the firms receiving grants. As shown by Coberly et al. (2011), CEM matching usually outperforms both propensity score matching (PSM) and Mhalanobis distance matching

[7] With centralized interaction variables, we can evaluate the direct effect of a grant as what happens when the RCA-index is zero, that is, when we evaluate the effect at the mean.

[8] The RCA-index is, however, not unproblematic. For example, Hinloopen and Van Marrewijk (2001) observed that the average value for the RCA-index typically was greater than one and that this result is an outcome of the chosen specification of the index. Hoen and Oosterhaven (2006) suggest an additive RCA index, centered around zero. Additional attempts to characterize comparative advantages includes Michelaye index that range from − -1 to 1. In the econometric analysis, we re-balance the RCA-index to be centered around zero, which to some extent also deals with the average value problem discussed above. We may also note that the RCA-index has been criticized by Yeats (1985), who found that the index was not reliable as a cardinal or ordinal index in a cross-country comparison. Further attempts to modify the RCA-index have been carried out by, for example, Hoen and Oosterhaven (2006), Yu et al. (2009), and Bebek (2011).

Table 2 Average RCA-index, by region

	Average RCA-skill: supply of high-skilled labor
Big cities	0.22
Support areas A&B	− 0.31
Other Areas	− 0.04
Total: Sweden	0.00

Note: RCA-index centered around zero

(MDM) in terms of reducing the imbalance between the treatment and control group. The combination of its intuitive approach, good statistical properties, and easy-to-use has made CEM matching increasing popular in applied empirical work. For recent applications of this matching method, see Croce et al. (2013), Cumming et al. (2017), and Grilli and Murtinu (2014).[9]

The matching is based on variables that are relevant for both program participation and program outcomes, and the key idea is that all matching variables should be as similar as possible between the control and treatment groups. Unlike PSM, CEM does not estimate the probability of being treated, but instead it coarsens variables into strata and puts different weights on the control firms depending on how close they are to the treated firms (Iacus et al. 2011, 2012). Detailed descriptions of CEM can be found in Blackwell et al. (2009) and Iacus et al. (2011, 2012). The matching performed in this paper is a so-called one-to-one matching, which yields one control firm for each treated firm. Consequently, we do not need to take matching weights into consideration to adjust for differences in the number of observations between the treated and control groups. For each of the treated firms, we match on firm properties 1 year before the treatment, ($t-1$), with t being the year a firm receives a grant (Caliendo and Kopeinig 2008). Firms receiving multiple R&D subsidies have been removed from the sample.

Results from the matching are presented in Table 4. As noted by Iacus et al. (2011, 2012), the value of the imbalance test is subordinate to the change in imbalance as given by matching. As shown in Table 4, matching reduces the imbalance for all variables, suggesting that matching leads to a control group that is more similar to the treatment group than to the collection of all non-treated firms.

Table 5 displays the matching results when the region of the treated firm is added as an (exact) matching variable, forcing the control firm to be in the same region as the treated firm. This creates a perfect balance between the treatment group and the control group on the regional variable. Having the "twin" firm located in the same region as the treated firm removes the possibility that subsequent changes in the development of the treated and control firms is due to location. We may also note that matching results from this matching strategy correspond strongly to the matching results presented in Table 4, where no geographical concern was included in the matching. However, forcing the control firm to be located in the same region as the treated firm reduces the number of matched pairs, which is seen when comparing the lower panels of Tables 4 and 5.

Finally, Table 6 provides the mean values of our outcome variables—employment, sales, and labor productivity—divided into six categories. The outcome variables are reported for all firms, treated firms, treated firms before treatment, treated firms after treatment, firms in the control group (original match), and firms in the control group when we include region as a matching variable. Here, we note that subsidized firms have slightly different mean outcome values before and after treatment and that there are some initial differences in the mean outcomes comparing the subsidized and control firms.

5 Models

5.1 Model specifications

As noted above, a main purpose of the analyzed grants is to promote growth and competitiveness in targeted firms, whereas the type of growth desired is less clear. To tackle this problem, we analyze the effects of the

[9] Two critical assumptions behind the matching is unconfoundedness, which in essence means that after the matching process, assignment to treatment can be seen as random, and ignorability that presumes that the treatment variable is independent of the potential outcomes Tiv{Yi(0), Yi(1)}Xj. In non-experimental set-ups, these assumptions cannot be directly tested, but researchers have instead developed sensitivity analyses to assess their plausibility (Luna and Lundin 2009; Imbens 2004; Rosenbaum 2002). We note that both assumptions hinges on access to detailed information on the objects of concern. In this vein, we note that the dataset used here is fairly rich, allowing us to apply the relevant matching variables. In addition, the analysis is based on FE-estimations eliminating time invariant unobserved fixed effects. Lastly, as a robustness test, we in subsequent regressions estimate models using different matching set-ups as well as FE-models on treated only (ATT), resulting in similar results. This is interpreted as an indication that the results are robust w.r.t. the method of choice.

Table 3 Variable description

Variable	Description (level of unit)	Data source	Mean	Stdv.
ln(*L*)	Log. of number of employees (firm)	IFDB	1.11	1.08
ln(*Lp*)	Log. of inflation adjusted value added per emp. (firm)	IFDB	5.83	0.83
ln(*sales*)	Log. of sales (firm)	IFDB	7.90	1.60
Wage premium	Mean of wage premium for skilled labor, divided by sni5 codes (firm)	LISA	1.93	1.68
ln(*K*)	Log. of physical capital (firm)	IFDB	4.95	1.90
RCA skill FA	(Skill FA/Emp FA)/(Skill Swe/Emp Swe) (regional)	LISA	0	0.23
Post-treatment	1 = period after support, 0 = otherwise (firm)	MISS, IFDB	0.0004	0.02
Treatment	Annually awarded grant/sales (firm)	MISS, IFDB	0.115	0.19
R&D/Ind.	Share of researchers by industry (industry)	LISA	0.117	1.36
Profit quota	Operating profit/ production value (firm)	IFDB	− 0.52	69.3
Share of higher educ.	Number of higher educ./total (firm)	RAMS	0.26	0.36
R&D int. SSY	Share of researchers by industry/ total number of emp. (Industry)	LISA	0.01	0.09
ln(*value added*)	ln(*L*) in period ($t-1$) (firm)	IFDB	6.97	1.47
ln(*W*)	Log. of inflation adjusted value added (firm)	LISA	5.15	0.79

Notes: Treatment is calculated as grant divided by net sales. Observations where the grant is larger than the net sales, or where repayment transactions are observed, are excluded from the analysis. The Swedish Agency for Growth Policy Analysis is responsible for the MISS database and the register database IFDB. The databases RAMS and LISA are from Statistics Sweden

Table 4 CEM matching results, matching imbalance, and number of matched pairs

Matching variables	Employment	Sales	Labor productivity
ln(*K*)		0.04 (0.29)	
Profit quota	0.02 (0.11)	0.03 (0.11)	0.03 (0.11)
ln(*value added*)	0.04 (0.45)		
ln(*W*)	0.10 (0.38)		
R&D int. SSY	0.02 (0.22)	0.01 (0.26)	0.01 (0.26)
ln(*L*)		0.03 (0.35)	0.01 (0.35)
Share of higher educ.	0.02 (0.48)	0.02 (0.49)	0.01 (0.49)
ln(*capital intensity*)			0.07 (0.24)
Overall (L1)	0.56	0.38	0.46
Number of matched pairs			
Total Sweden	481	464	468
Big cities	182	168	166
Support areas A&B	28	38	38
Other areas	271	258	264
1–10 employees	293	278	280
11–50 employees	154	153	154
50+ employees	34	33	34

Note: Results from 1-1 matching. Matching imbalance, univariate L1 distance between treated and control group, imbalance between treated and all other firms within parentheses (.)

Table 5 CEM matching results, including region as a matching variable

Matching variables	Employment	Sales	Labor productivity
Region	0.00 (0.19)	0.00 (0.17)	0.00 (0.17)
ln(*K*)		0.08 (0.29)	
Profit quota	0.02 (0.11)	0.04 (0.11)	0.04 (0.11)
ln(*value added*)	0.06 (0.45)		
ln(*W*)	0.10 (0.38)		
R&D int. SSY	0.04 (0.22)	0.04 (0.26)	0.04 (0.26)
ln(*L*)		0.07 (0.35)	0.08 (0.35)
Share of higher educ.	0.06 (0.48)	0.15 (0.49)	0.17 (0.49)
ln(*capital intensity*)			0.14 (0.24)
Overall (L1)	0.71 (1.00)	0.66 (0.99)	0.71 (0.99)
Number of matched pairs			
Total Sweden	396	275	282
Big cities	164	115	119
Support areas A&B	18	15	16
Other areas	214	145	147
1–10 employees	241	178	183
11–50 employees	127	80	82
50+ employees	28	17	17

Note: Matching imbalance, univariate L1 distance between treated and control groups, imbalance between treated and all other firms within parentheses (.)

Table 6 Mean values for dependent variables

	All	Subsidized firms	Subsidized firms—before treatment	Subsidized firms—after treatment	Control group (original match)	Control group (match on regions)
ln(*L*)	1.17	2.21	2.19	2.30	1.95	1.84
	(1.09)	(1.26)	(1.28)	(1.20)	(1.34)	(1.37)
ln(*sales*)	8.01	8.91	8.92	8.89	9.03	8.70
	(1.55)	(2.01)	(2.01)	(2.03)	(1.81)	(1.71)
ln(*Lp*)	5.89	6.05	6.04	6.06	6.12	6.21
	(0.77)	(0.73)	(0.71)	(0.81)	(0.69)	(0.80)

Note: Standard deviation within parentheses (.)

R&D grants on a set of outcome variables capturing various aspects of firm growth and competitiveness. More specifically, we will analyze how the grants impact employment, sales, and labor productivity. As pointed out by Delmar et al. (2003), employment represents an input variable and a measure of growth in resources, while sales represents an output variable and a measure of the acceptance of the product or service in the market. Combined these measures are closely related to labor productivity making it interesting to analyze these aspects of competitiveness.[10]

In the analysis, we estimate matched differences-in-differences (DID) regressions and, as a robustness test, we employ fixed-effects (FE) regressions on treated firms only. Hence, while the first method seeks to analyze the performance of the treatment group vs. a set of similar firms that did not receive any R&D grants, the latter method seeks to detect trend breaks in firm development at the time of or after receiving the grants. The model specifications are chosen based on the existing literature in each respective area. Because the choice of model is central to the analysis, we will present each model in more detail.

5.2 Labor demand

The labor market literature is relatively clear on the specification of the employment model. A firm's demand for labor is derived from the production function where firms, for a given set of factor prices, decide on the combination of input factors that are consistent with profit maximization (Hijzen and Swaim 2008). Furthermore, we allow for the adjustment costs of the labor force. Adjustment costs are handled by including a dynamic lag of the number of employees as an explanatory variable (Cahuc and Zylberberg 2004), thus shifting the analysis toward a dynamic panel data model specification (Angrist and Pischke 2008). To handle the endogeneity problem associated with a lagged dependent variable as an explanatory variable, we apply Han and Phillips' (2010) dynamic panel estimator. Compared to the commonly used GMM-estimators that rely on the absence of second order autocorrelation in the residual and a properly specified instrument matrix (Arrelano and Bond 1991; Blundell and Bond 1998), the Han and Phillips (2010) estimator tackles the endogeneity problem through its differencing design. The Han and Phillips (2010) estimator is known for having good short panel properties and avoiding much of the weak moment condition problem that is known to affect conventional GMM estimation when the autoregressive coefficient is near unity. Thus, to evaluate the effects of public R&D grants on employment, we estimate the following augmented labor demand model:

$$\begin{aligned}\ln(L)_{\mathrm{it}} = {} & \alpha_{\mathrm{i}} + \beta_{\mathrm{l}}\ln(L)_{\mathrm{it-1}} + \beta_{\mathrm{w}}\ln(w)_{\mathrm{it}} + \beta_{\mathrm{y}}\ln(y)_{\mathrm{it}} \\ & + \beta_{\mathrm{T}}(\mathit{treatment})_{\mathrm{it}} + \beta_{\mathrm{p}}(\mathit{post})_{\mathrm{it}} \\ & + \beta_{\mathrm{R}}(\mathrm{RCA})_{\mathrm{rt}} + \beta_{1}\Big[(\mathrm{RCA})_{\mathrm{rt}} \\ & \cdot \Big(\mathit{treatment}\Big)_{\mathrm{it}}\Big] + \beta_{2}\Big[(\mathit{RCA})_{\mathrm{rt}} \\ & \cdot \Big(\mathit{post}\Big)_{\mathrm{it}}\Big] + \beta_{3}(\mathit{skill\text{-}share})_{\mathrm{it}} + \beta_{4}(\pi)_{\mathrm{it}} \\ & + \upsilon_{\mathrm{i}} + \gamma_{\mathrm{t}} + \varepsilon_{\mathrm{it}}\end{aligned} \tag{2}$$

where β_l reflects the effect from the number of employees in the previous period (l_{it-1}) and implicitly depends on the size of the adjustment costs, w_{it} is wage in firm *i* and year *t*, and *y* is value added, *treatment* is a dummy for the year the firm receives the grant, whereas

[10] Hence our focus is more a real side analysis than a study of the financial aspects, which we leave for future research.

post captures the post treatment period. Regional differences in the supply of skilled labor are captured by the RCA-index *RCA*, where a value above zero indicates that a region has a relative abundance of skilled labor. Hence, the interaction between the regional supply of skilled labor and the treatment indicators captures asymmetric effects in how the grants impact firm performance in different regions. To control for firm-specific human capital and profitability (variables that may impact innovation, firm performance, and the likelihood of receiving support), the model is augmented with firms' profit ratio π and the share of the labor force with tertiary education (*skill-share*); firm- and -year fixed effects are captured by υ_i and γ_t, respectively, and finally, ε_{it} is the error term.

5.3 Sales

Two commonly used measures when analyzing firm growth are number of employees and sales. Number of employees represents an input variable and a measure of growth in resources, while sales represents an output variable and a measure of the acceptance of the product or service in the market (Delmar et al. 2003). For input variables, it is reasonable to expect positive effects for firms receiving a grant. However, the effect on output variables is unclear (Gustafsson et al. 2016). How sales are affected by the R&D grants can also be influenced by the fact that the subsidy program descriptions state future sales growth as a relevant key variable. Hence, following the commonly applied Cobb-Douglas production function approach, the augmented sales model takes the following form (Felipe and Gerard Adams 2005):

$$\begin{aligned}\ln(S)_{it} = {} & \beta_k \log K_{it} + \beta_l \ln(L)_{it} + \beta_T(treatment)_{it} \\ & + \beta_p(post)_{it} + \beta_R(RCA)_{rt} + \beta_1\Big[(RCA)_{rt} \\ & \cdot \Big(treatment\Big)_{it}\Big] + \beta_2\Big[(RCA)_{rt} \\ & \cdot \Big(post\Big)_{it}\Big] + \beta_3(skill\text{–}share)_{it} + \beta_4(\pi)_{it} \\ & + \beta_5(R\&D)_{it} + \upsilon_i + \gamma_t + \varepsilon_{it} \qquad (3)\end{aligned}$$

where we have the same set of fix-effect, regional-, and treatment indicators as in Eq. (2), but note that the dependent variable here, sales, is represented by S_{it}, K is the firm capital stock, L is the employment, and finally, *R&D* is the firm level R&D-intensity.

5.4 Labor productivity

As a complementary measure to employment and sales, we look at labor productivity, which can be seen as a combination of the relative impact of the grants on employment and production. To study labor productivity effects, we follow Griliches (1986) to obtain the following augmented labor productivity (*Lp*) model:

$$\begin{aligned}\ln(lp)_{it} = {} & \beta_{k/l}\ln(K/L)_{it} + \beta_l \ln(L)_{it} \\ & + \beta_T(treatment)_{it} + \beta_p(post)_{it} \\ & + \beta_R(\mathrm{RCA})_{rt} + \beta_1\Big[(RCA)_{rt} \\ & \cdot(treatment)_{it}\Big] + \beta_2\Big[(RCA)_{rt} \\ & \cdot(post)_{it}\Big] + \beta_3(skill\text{–}share)_{it} + \beta_4(\pi)_{it} \\ & + \beta_5(R\&D)_{it} + \upsilon_i + \gamma_t + \varepsilon_{it} \qquad (4)\end{aligned}$$

where $\beta_{k/l}$ is a measure of the productivity elasticity with respect to the capital intensity in the firm. The coefficient for number of employees, β_l, is a scale indicator; if $\beta_l = 0$, this is a sign of constant returns to scale, $\beta_l > 0$ and ($\beta_l <$ 0) signal increasing (decreasing) returns to scale, respectively.[11]

6 Results

6.1 Overview of results

An overview of the sign and significance of the treatment and post-treatment effects is depicted in Table 7, and a corresponding overview of the results from our robustness checks can be found in Table 8. Table 9 in the Appendix contains the basic results on how the R&D grants impact our three outcome variables: employment, sales, and labor productivity and shows the effects from both matched DID estimations and FE estimations on treated firms only. In

[11] The reason for not using a dynamic model specification is that the non-dynamic formulation is more frequently used when labor productivity is evaluated (Chansarn 2010).

Table 7 Summary of regression results

	Employment	Sales	Productivity
Treatment	Non-significant	Negative significant (−)	Non-significant
Post-treatment	Non-significant	Non-significant	Non-significant
RCA skill ∗ treatment	Non-significant	Non-significant	Non-significant
RCA skill ∗ post-treatment	Non-significant	Positive significant (+)	Positive significant (+)

Note: See Table 9, columns 1–3, for the complete model

this paper, our focus will be on the DID results because these can be considered more precise, but as we will observe, the results from the DID estimations and the more naive fixed effects estimations are rather similar, which we interpret as a sign of robustness of the results. The key results are depicted in Figs. 1, 2, and 3 and summarized in Table 7, where the treatment period corresponds to periods when the grant is paid out to the receiving firm, and the post-treatment period corresponds to the period after which the firm no longer receives support. We may also note that the first set of CEM matched regression results presented is based on a matching where we are not forcing the "twin" firm to be located in the same labor market region as the treated firm.[12] Hence, in these first estimates, we cannot exclude the possibility that a part of the treatment effect can be influenced by regional differences in the location of treated and control firms. In subsequent regressions, this matter will be examined in more detail.[13]

6.2 Effects on employment

A goal prioritized by the government is to generate new jobs. Hence, employment is one of the analyzed outcome variables. However, as shown in Table 7, there are no statistically significant employment effects of the analyzed grants. That is, we do not find evidence of a direct employment effect of the grants at the time of the payment, nor in the post-treatment period. What should be noted is that the estimated direct effect represents the average effect across all regions. To uncover the potential heterogeneity of the impact of the R&D grants, we turn to the interaction between the received grant and regional characteristics. Studying the regional interaction, the first thing to note is that the estimate is positive but not statistically significant, suggesting a positive relation between employment that is not significant at the *midpoint* of our sample (RCA-index = 0), as illustrated in Fig. 1 and given by the estimates in Table 9.

When interpreting the above result, we note that the estimated coefficient reflects the mid-point estimate and does not reveal the marginal effect of the grants at the endpoints of the distribution. The full cross-regional variation in the impact of the R&D grants is illustrated in Fig. 1, suggesting a varying effect across our 60 labor market regions that goes from a negative and significant effect in regions at the low end of the human capital supply ranking to a positive and significant effect in the regions with the most abundant human capital (during the period when the grant is paid out). For the post-treatment effect, however, the estimate never becomes positive and significant as we move toward more skill-abundant regions. This spread in marginal effects is an example of how information can be hidden behind the average effect. We also note that the results discussed here are based on CEM-matching without forcing the treated and control firm to be located in the same region. Hence, if there are systematic differences in the locations of treated and control firms, not controlling for location may impact the estimates of the treatment effect. In subsequent regressions, we will analyze whether controlling for location upsets the results.

6.3 Effects on sales

Together with employment, sales are a commonly applied indicator of firm growth. If firms are able to increase their efficiency, sales can be increased without a matched increase in the labor force. The results from the sales regressions are given in columns 2 and 5 in Table 9, and the regional distribution of the marginal effect (matched DID estimates) is depicted in Fig. 2. Figure 2 reveals a series of interesting observations.

[12] There is a total of 60 labor market regions, defined such that most of the work-home commuting takes place within the region and that it is possible to commute between "any two points" in each region.

[13] We also note that the RCA-index captures relative local supply of human capital, whereas potential drivers behind this clustering are left aside. An interesting route for future research is therefore to continue and analyze drivers of the clustering of human capital.

Table 8 Summary of regression results, robustness estimates

	Employment	Sales	Productivity
Treatment	Non-significant	Negative significant (−)	Non-significant
Post-treatment	Non-significant	Non-significant	Non-significant
RCA skill ∗ treatment	Non-significant	Non-significant	Non-significant
RCA skill ∗ post-treatment	Non-significant	Positive significant (+)	Positive significant (+)

Note: See Table 10, columns 4–6, for the complete model

First, at the time of the treatment, there is a tendency of a negative drift in sales, and the negative effect is largest in regions with abundant human capital. One possible explanation for this result is that the grant triggers investment, which leads to a temporary reallocation of productive resources from production to investment activities; this effect may be largest in human capital-abundant regions. However, when we move from the period of treatment to the post-treatment period, the picture is reversed. After the treatment period (after which the grant has been paid out), we find a negative and significant effect on sales for firms in regions with a relatively small share of high-skilled workers and a positive but not significant effect for firms in regions with an abundance of high-skilled workers. We may note that this post-treatment pattern is consistent with the hypothesis that the largest investments take place in firms located in human capital-abundant regions, leading to more positive sales development in subsequent years.

6.4 Effects on productivity

The impact of the grants on productivity can be seen as a weighted employment and sales effect. As noted above, the effect of the grants on employment and sales was negative during the treatment period, although not significant for employment. Hence, expectations for labor productivity are not obvious. Looking at the DID results in Table 9, the direct effect of the grants is negative but not significant, both during and after the treatment.

The regional spread in labor productivity effects is illustrated in Fig. 3, which indicates no significant treatment effects in any type of region during the treatment. However, for the post-treatment period, we note that in line with the findings for sales and employment, a more positive (or less negative) productivity effect is found in regions with an abundance of high-skilled workers. To be precise, as we move from the least to the most skill-abundant region, the post-treatment effect on labor productivity goes from negative and significant to barely positive and significant in the most skill-abundant regions. Hence, the probability of a positive post-treatment effect on sales, employment, and productivity is highest in skill-abundant regions. These results are, to some extent, consistent with earlier studies that found the most positive effects of similar grants in central rather than rural regions (Banno et al. 2013; Herrera and Nieto 2008; Piekkola 2007). This result allows us to speculate whether it may be the lack of high-skilled workers that puts growth restrictions on innovative SMEs in regions with a low

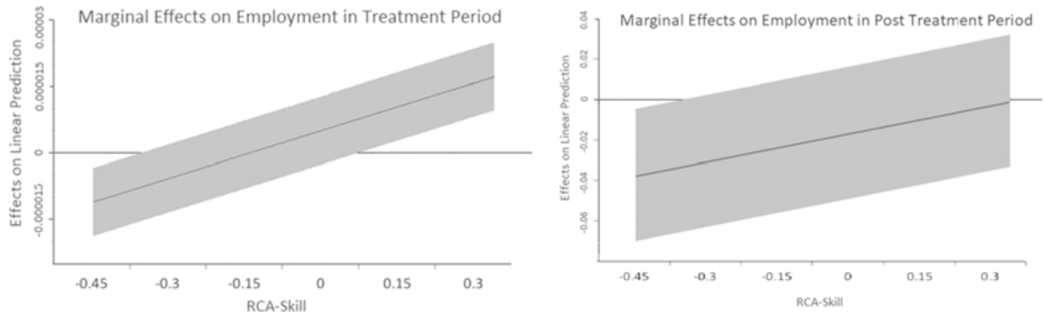

Fig. 1 Marginal effects on employment. Notes: All figures are constructed with non-clustered standard errors. The confidence intervals regarding the employment effects are only correct for RCA-index = 0. The figures are based on CEM matched DID estimations from Table 9

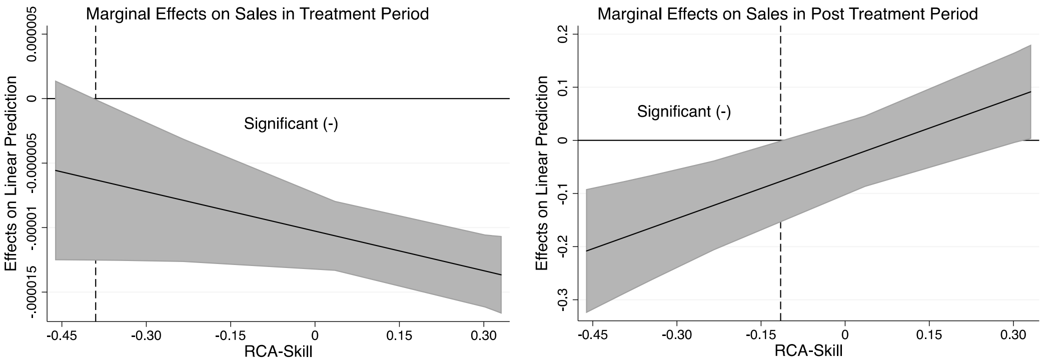

Fig. 2 Marginal effects on sales. Notes: All figures are constructed with non-clustered standard errors. The figures are based on CEM matched DID estimations from Table 9. Due to technical limitations in retrieving marginal effects at different percentiles when using clustered standard errors, estimates, depicted in Figs. 2 and 3, are based on non-clustered standard errors.

RCA-skill index. However, because firm location is not included as a matching variable in these regressions, we at this stage cannot rule out the possibility that these results may be driven by a systematic difference in location between treated firms and the control group. In the subsequent section, we will take a closer look at the robustness of these results when controlling for firm location.

6.5 Robustness checks

The analysis above does not guarantee a complete separation of the effect of being localized in a specific labor market region from the effect of the grant. To rule out the possibility of location-driven bias, we redo our matching and include regions as an exact matching variable, forcing the control firm to be localized in the same labor market region as the treated firm. Hence, any differences in results between Tables 9 and 10 signal a locational selection bias in Table 9 where we do not force the matched firm to be located in the same labor market region as its matched twin firm.

Studying the summarized results Table 8, we find that the results before and after matching on region are quite similar; when there is a significant effect in Table 8, we always find a corresponding effect in Table 7 in both sign and (approximately) size. Consequently, forcing the control firm to be located in the same local labor market region as the subsidized firm does not significantly alter the results. These observations lead us to two noteworthy results. First, matching on location does not impact the overall instantaneous effect or the post-treatment effect. The grants have, considered over all regions, no significant post-treatment effect on employment, sales, or productivity. However, an immediate dip in sales and labor productivity can be found. Secondly, turning to the regional dimension, starting with the

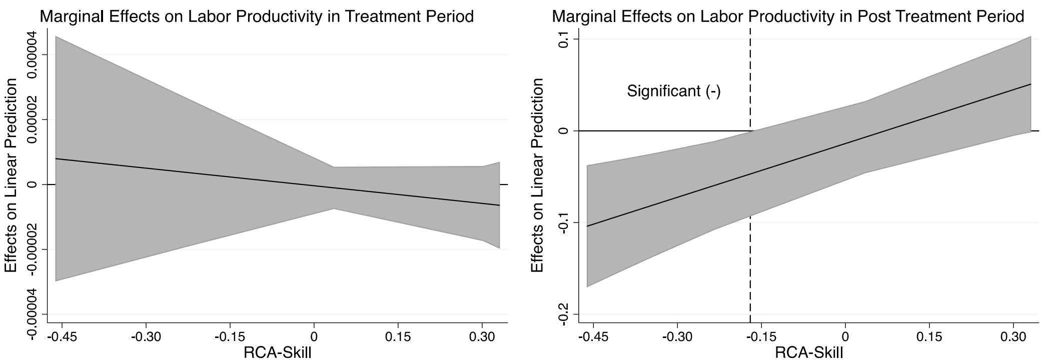

Fig. 3 Marginal effects on labor productivity. Notes: All figures are constructed with non-clustered standard errors. The figures are based on CEM matched DID estimations from Table 9

regional distribution of the instantaneous effect, we find no significant midpoint interaction effects. For the post-treatment period, however, we find a positive interaction between the regional supply of skilled labor and receiving a grant on sales and productivity. This significant interaction suggests that grants have a more positive post-treatment effect on firms located in human capital-abundant regions than in other regions. Given that the treated and control firms are in the same region, this asymmetry can occur if the agency administrating the grants is systematically targeting more successful firms in human capital-abundant regions compared to other regions.

We may also consider the possibility that receiving a grant generates a temporary competitive advantage. Given that the prospects of growth for innovative SMEs are likely to be better in human capital-abundant regions than in other regions, the marginal return is also likely to be higher in human capital-abundant regions. Hence, given that we ignore distributional issues and potential distortions caused by the grants and focus on growth in targeted firms, the results suggest that if firm growth is the primary goal of the program, R&D grants focused on innovative SMEs tend to generate the largest growth effects when they are given to firms located in human capital-abundant regions.

As an additional robustness test, we re-estimate the models in columns 1–3 in Table 9 using spell-fixed post-treatment periods. The results from these additional robustness checks are presented in Table 11 and fixed to 2 respectively 3 years after treatment. The estimated effects almost exactly correspond to the estimated post-treatment effects in Table 9. Hence, we conclude that following the treated firms for a fixed post-treatment period, in comparison to following each treated firm for all available post-treatment years, yields similar results for all outcome variables. This further strengthens our belief in the results found above.

7 Conclusions

The central question discussed in this paper is whether the effects of public innovation grants to private firms vary depending on firm location and the surrounding environment. Why regions matter for the success of different industries has been discussed by, for example, Marshall (1920), Asheim et al. (2011), Cooke (2001), and Tödtling and Trippl (2005). A common feature of these studies is that they all agree that regional context matters for firm location and growth; i.e., there is interdependence between firm performance and the surrounding environment. In this vein, it is well known that access to skilled labor is crucial for the innovation and development of innovative SMEs, or, as noted by Kunz (2014) regarding the US situation: "A common complaint from 21st century manufacturers is having access to a skilled workforce, …, Currently, nine out of ten manufacturers are having difficulty finding skilled workers, and they say this is directly hurting the bottom line."

This paper analyzes one dimension of how the regional supply of skilled labor influences the prospects of firm growth by examining local abundance of skilled labor and regional variation in relation to the impact of public R&D grants targeting innovative SMEs. Specifically, we analyze the effects of two R&D subsidy programs on firms' employment, sales, and labor productivity and how the impact of these grants co-varies with the regional relative supply of skilled labor. Hence, potential drivers behind the clustering of human capital are not analyzed.

We divide the results into the impact during and after the treatment. During the treatment period when the firms are receiving financial support, we find a significant and negative effect on sales and a non-significant treatment effect on firm employment and labor productivity. The negative effect on sales in the treatment period could be associated with within firm reallocation effects when the R&D grant is received. One can, for example, consider an investment that for a transitional period of time leads to a reallocation of resources from production to investment related activities. After the treatment period has ended, there is no evidence of any significant effects on sales, employment, and labor productivity.

Adding the regional dimension to the analysis, we find that the effect of the grants differs across regions. In the *treatment period*, the employment effect goes from negative and significant to positive and significant whereas sales develop in the opposite direction. For labor productivity, the effect is non-significant for all type of regions. In the *post-treatment period*, the pattern is clear. For both sales and productivity, we find a positive drift as we move from the least to the most skill-abundant labor market region. To be precise, the marginal effect of the grant goes from negative and significant to positive and significant as we move from the least to the most skill-abundant region. For employment, there is a less clear positive trend with mostly insignificant employment effects.

In conclusion, the treatment effect of the analyzed innovation grants can be negative for firms in some regions, not significant in others, and significantly positive for firms in the most human capital-abundant regions. Hence, the findings of this paper indicate that the better regional surroundings a firm faces, in terms of human capital-abundance, the higher is the probability that the recipient of an R&D grant will show positive growth effects after receiving a grant. Accordingly, with the firm growth focus of this paper in mind, these results yield the following policy implication. If the aim is to maximize the growth effects of public R&D grants, it can be counterproductive to distribute R&D grants too evenly across regions. However, the policy-maker may have other reasons for distributing R&D grants than to maximize the growth effects that justify an equal spread of grants across regions. One may also note that regions have different comparative advantages, implying that regions less suited for R&D-intensive activities may be better suited for other type of activities.

Overall, our finding that better regional surroundings in terms of human capital-abundance increase the probability of positive growth effects from publicly founded R&D and innovation grants makes intuitive sense and is also consistent with findings of earlier literature suggesting that R&D grants generate larger effects in central rather than rural regions (Banno et al. 2013; Herrera and Nieto 2008; Piekkola 2007).

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Appendix

Table 9 The effect of R&D grants—results of CEM matching (left) and results of FE-regressions (right)

	DIDHan-Philips ln(*L*)	DID ln(*sales*)	DID ln(*Lp*)	FE Han-Philips ln(*L*)	FE ln(*sales*)	FE ln(*Lp*)
Treatment	−5.88e−06 (3.79e−06)	−0.00001 (2.49e−06)***	−3.99e−07 (3.99e−06)	−5.77e−06 (3.99e−06)	−9.9e−06 (2.3e−06)***	−1.40e−06 (3.45e−06)
Post-treat	−0.0157 (0.0163)	−0.0338 (0.0512)	−0.0138 (0.0266)	−0.0035 (0.0186)	−0.0558 (0.0559)	−0.0164 (0.0287)
RCA skill	−0.0721 (0.1036)	−0.3412 (0.5826)	−0.1866 (0.2226)	0.0470 (0.1588)	−0.3595 (0.6580)	−0.1561 (0.2440)
RCA skill ∗ treatment	3.75e−05 (2.89e−05)	−0.00001 (9.94e−06)	−1.81e−05 (3.04e−05)	3.62e−05 (3.04e−05)	−1.2e−05 (9.01e−06)	−1.47e−05 (2.6e−05)
RCA skill ∗ post-treat	0.0480 (0.0643)	0.3782 (0.1715)**	0.1954 (0.0817)**	0.0400 (0.0700)	0.3805 (0.1727)**	0.1871 (0.0818)**
ln(*K*)		0.0921 (0.0292)***	0.0760 (0.0135)***		0.0921 (0.0318)***	0.0764 (0.0147)***
ln(*L*)		0.7901 (0.0609)***	−0.0119 (0.0325)		0.7867 (0.0666)***	0.0014 (0.0337)
Profit ratio		0.0021 (0.0003)***	1.4099 (0.1887)***		0.0021 (0.0003)***	1.6463 (0.1273)***
Share of higher educ.		−0.4073 (0.1593)**	−0.1052 (0.0875)		−0.4566 (0.1781)**	−0.0834 (0.0976)
R&D int.		0.0842 (0.2753)	0.0701 (0.1150)		0.1183 (0.3048)	0.0381 (0.1272)
ln(*L* (*t* − 1))	0.8539 (0.0446)***			0.8977 (0.0658)***		
ln(*y*)	0.2363 (0.0063)***			0.2374 (0.0089)***		
ln(*w*)	−0.2800 (0.0097)***			−0.2771 (0.0144)***		
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	7761	7439	6868	3669	3745	3330

Notes: *, **, *** indicate significance at the 10, 5, and 1% levels, respectively. Clustered standard errors within parentheses (.). The matching method is 1-1 coarsened exact matching. Only firms receiving R&D grants are included in the FE-estimations. Both treated firms and matched twins are included in the difference-in-differences estimations. The employment model is estimated with the Han-Philips (2010) linear dynamic panel data regression

Table 10 The effect of R&D grants: regions included in CEM matching

	DID Han-Philips ln(*L*)	DID ln(*sales*)	DID ln(*Lp*)	DIDHan-Philips ln(*L*)	DID ln(*sales*)	DID ln(*Lp*)
Treatment	−1.13e−06 (8.16e−07)	−0.00001 (2.0e−06)***	−3.30e−06 (4.5e−07)***	−6.54e−06 (4.01e−06)	−0.00001 (2.5e−06)***	−1.31e−06 (3.51e−06)
Post-treat	−0.0093 (0.0171)	−0.0379 (0.0542)	−0.0106 (0.0286)	−0.0110 (0.0172)	−0.0497 (0.0538)	−0.0146 (0.0277)
RCA skill				0.0751 (0.1230)	−0.3644 (0.6413)	−0.1482 (0.228)
RCA skill ∗ treatment				4.21e−05 (3.06e−05)	−0.00001 (9.98e−06)	−0.00002 (0.00003)
RCA Skill ∗ post-treat				0.0583 (0.0663)	0.3789 (0.1724)**	0.1988 (0.0812)**
Full model	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	6392	4962	4477	6392	4962	4477

Notes: *, **, *** indicate significance at the 10, 5, and 1% levels, respectively. Clustered standard errors within parentheses (.). The matching method is 1-1 coarsened exact matching. Both treated firms and matched twins are included in the difference-in-differences estimations. See Table 9 and the description of the model for the full model, control variables, etc. The employment model is estimated with the Han and Phillips (2010) linear dynamic panel data regression

Table 11 Spell-fixed post-treatment period

	DID Han-Philips ln(*L*)	DID ln(*sales*)	DID ln(*Lp*)	DIDHan-Philips ln(*L*)	DID ln(*sales*)	DID ln(*Lp*)
	Three years fixed post-treatment period			Two years fixed post-treatment period		
Treatment	−5.2e−06 (3.87e−06)	−0.00001 (2.4–06)***	2.89e−06 (4.02e−06)	−5.57e−06 (3.78e−06)	−0.00001 (2.5e−06)***	−3.22e−07 (3.95e−06)
Post-treat	−0.0037 (0.0183)	−0.0292 (0.0543)	−0.0003 (0.0259)	−0.0227 (0.0165)	−0.0329 (0.0533)	−0.0101 (0.0269)
RCA skill	0.0288 (0.1173)	−0.0077 (0.4933)	−0.0834 (0.2582)	0.1201 (0.1158)	−0.2909 (0.5404)	−0.1980 (0.2513)
RCA skill ∗ treatment	0.00003 (0.00003)	−0.00001 (9.56e−06)	−0.00004 (0.00003)	0.00004 (0.00003)	−0.00001 (9.85e−06)	−0.00002 (0.00003)
RCA skill* ∗ post-treatment	0.0361 (0.0683)	0.4317 (0.1636)***	0.2429 (0.0807)***	0.0198 (0.0651)	0.3877 (0.1679)***	0.1944 (0.0849)***
Full model	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	7361	7169	6630	7511	7304	6748

Notes: *, **, *** indicate significance at the 10, 5, and 1% levels, respectively. Clustered standard errors within parentheses (.). The matching method is 1-1 coarsened exact matching. Both treated firms and matched twins are included in the difference-in-differences estimations. See Table 9 and the description of the model for the full model, control variables, etc. The employment model is estimated with the Han and Phillips (2010) linear dynamic panel data regression

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