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Abstract

This paper explores how firm-specific trade opportunities affect R&D investments and innovative activities. To construct trade opportunities that are exogenous to firm-level decisions, I use the variation in export and import patterns and exploit the fact that firms differ in their product-country exporting (sourcing) patterns. Both export and import opportunities generate growth in terms of sales, value-added, overall employees, and high-skilled employees. Despite having similar effects on firm growth, the effects on innovation activities are very different for the two trade shocks. Export opportunities lead to more R&D investments (spending, employees, and intensity) and innovations (product and process). On the other hand, import opportunities show no effects on R&D investments, and the impact on product, process, and service innovation is negative.

Keywords: R&D · Innovation · International trade · Export · Import
JEL: F10, F14, O31, O32

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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 Organization,

[1] From the literature on endogenous growth, we know that R&D, innovations, and the spill-over 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.

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 have very different impacts on firms' innovative activities, despite the similar impact on firm growth. 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 complementary 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

[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.

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 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

[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.

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 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 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; 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

[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.

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 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. Export demand and import supply 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 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. Export demand is the share of world import demand (ED_{ckt}), and import supply 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. One main concern with the original specifications, as in Hummels *et al.* (2014), is if, for example, an export supply of jeans fabric in the world only reflects that jeans jackets are in fashion right now, and therefore a Swedish firm producing jeans jackets, and similar firms in the rest of the world, buy more jeans fabric. In such a scenario increased imports might only reflect increased production in my firm and other firms producing jeans jackets, and not falling prices and/or increasing comparative advantage for someone. The argument is connected to the fact that inputs can be closely related to the end product.

An instrument reflecting the share of for example Indian jeans fabric out of all exported jeans fabric (minus share of jeans fabric exported to Sweden) should be a better indicator of Indian jeans fabric gaining market shares (due to falling prices or increased comparative advantage). A firm that already is a buyer of jeans fabric from India should benefit, and the increased comparative advantage should be reflected in a lower unit price. The new IS_{ckt} instrument is supposed to reflect someone gaining market shares (increased comparative advantage), which is to my understanding what we would like to capture with the original specification.

Export demand 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:

$$ED_{ckt} = \frac{ImportWorldValue_{ckt} - ImportSwedenValue_{ckt}}{ImportWorldValue_{kt} - ImportSwedenValue_{kt}} \tag{1}$$

Import supply 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:

$$IS_{ckt} = \frac{ExportWorldValue_{ckt} - ExportSwedenValue_{ckt}}{ExportWorldValue_{kt} - ExportSwedenValue_{kt}} \tag{2}$$

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:

$$ln(Y_{jckt}) = \alpha_{jck} + \gamma ED_{ckt} + \tau_t + \epsilon_{jt} \tag{3}$$

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}:

$$ln(Y_{jckt}) = \alpha_{jck} + \beta IS_{ckt} + \tau_t + \epsilon_{jt} \tag{4}$$

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 negative price changes, or possibly unchanged prices, 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.

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.

Table 1: Export Demand and Import Supply

Dependent variable :	(1) ln(value)	(2) ln(volume)	(3) 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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]

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

[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.

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

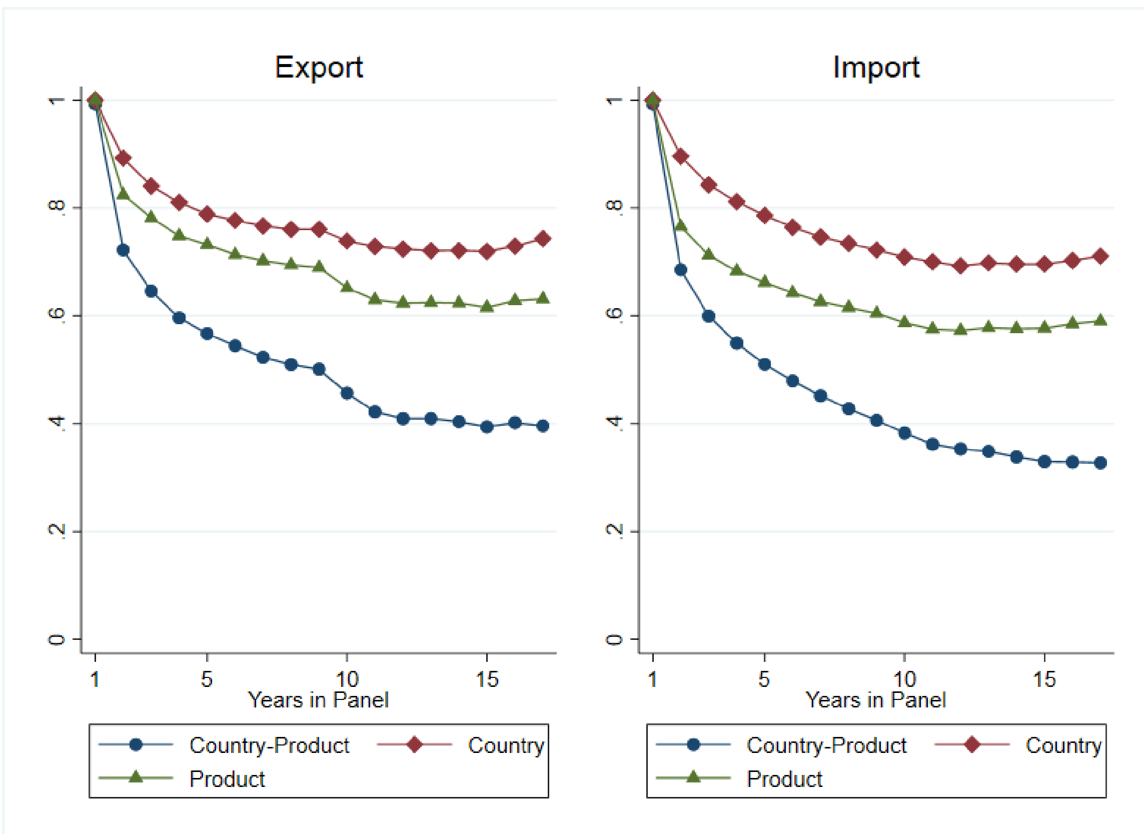

Figure 1: Mean firm-level trade weights

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:

$$ED_{jt} = \sum_{c,k} W^E_{jck} ED_{ckt} \tag{5}$$

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:

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

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:

$$Y_{jt} = \alpha + \beta ED_{jt} + \theta_j + I_k \times \tau_t + \varepsilon_{jt} \tag{7}$$

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 (7) 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 (7) 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, average 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.

[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.

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.

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.

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

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 by approximately 0.5 percent.

Table 3: Trade: Export and Import

	Export		Import	
	(1) Export/Sales	(2) ln(Export)	(3) Import/Sales	(4) ln(Import)
Export Demand	0.074^{***} (0.012)	0.542^{**} (0.240)		
Import Supply			0.022^{***} (0.007)	0.494^{***} (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 * ($p < 0.1$).

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 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]

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 * ($p < 0.1$).

3.2 Firm growth in sales, value-added, and employment

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

[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.

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 (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.

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 * ($p < 0.1$).

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.

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 * ($p < 0.1$).

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 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	0.038	0.934	0.060
	(0.663)	(0.089)	(0.680)	(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]

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 * ($p < 0.1$).

[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.

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]

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 * ($p < 0.1$).

[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 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 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. On the other hand, import opportunities do not seem to significantly affect R&D spending, and the estimated effects are about one-tenth of the effects from 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.

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.

One interesting venue for future research would be to contrast the findings in this paper to findings using other measures of innovations, such as patents. Would we find a similar pattern with increasing innovation when export demand surges and decreasing innovation when opportunities to import improve if we look at patents? Or is it possible that the way we define and measure innovation influences the outcomes? These questions are left for future studies to explore. It would also be of interest to investigate the relationship between changes in service-trade opportunities and R&D and innovations. For example, an outcome such as service innovation is likely to be directly affected by changes in the opportunities to trade services. Another important link to study in relation to R&D and innovation is the close connection between goods and services trade, where firms who sell services as complements to their goods also boost the demand for goods. How the increasing importance of the goods-services trade link relates to R&D and innovation at the firm level is also left for future studies to explore.

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A Appendix

A.1 Figures

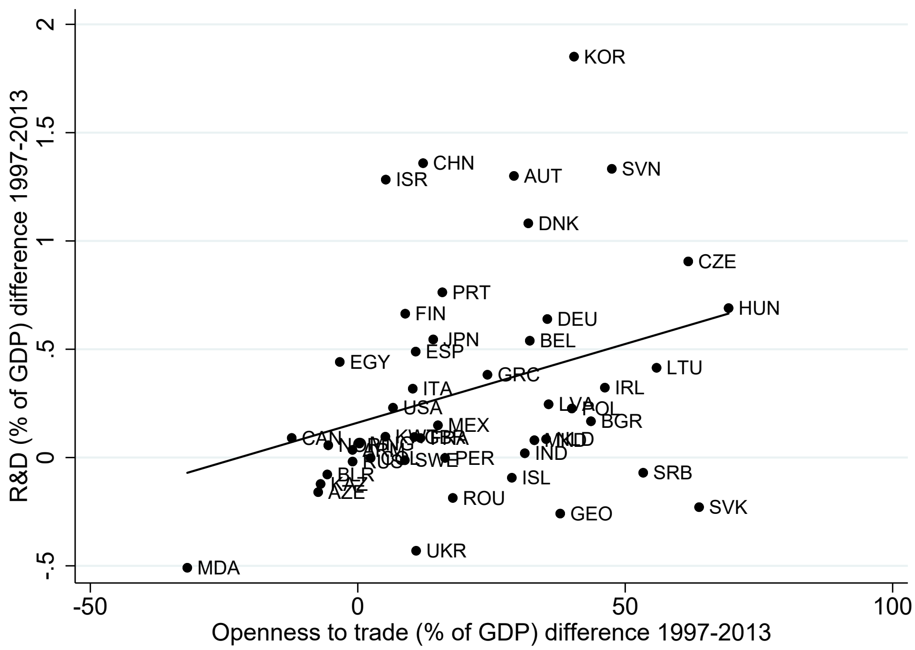

Figure A1: Country-level changes in openness to trade and changes in R&D (1997-2013)

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.

A.2 Alternative fixed effects

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 * ($p < 0.1$).

A.3 Models with both export demand and import supply

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 * ($p < 0.1$).

A.4 Models with lagged effects

A.4.1 Export demand

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 * ($p < 0.1$).

A.4.2 Import supply

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 * ($p < 0.1$).