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Global Demand, Local Ideas

THE IMPACT OF TRADE SHOCKS ON FIRM INNOVATION

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Abstract

This paper examines how firms' innovation activity responds to product- and destination-specific export demand shocks in their export markets. I draw on unique administrative data for Finnish manufacturing firms from 1999 onwards, matched with national customs records, patent data, and innovation and R&D surveys. The analysis reveals that positive export demand shocks significantly increase patenting activity and the likelihood of introducing new product innovations, while negative shocks reduce patenting and exports. The study finds that these innovation responses are dynamic, with patent applications rising in the short term and granted patents materializing over longer horizons. Heterogeneity analysis shows that more productive and financially stronger firms benefit disproportionately from export demand expansions. This pattern suggests that financial constraints may limit the ability of firms to adopt new innovations even as they expand production.

Tiivistelmä

Globaalit kysyntämuutokset, paikalliset ideat: Kauppasokkien vaikutus yritysten innovaatiotoimintaan

Tässä tutkimuksessa tarkastellaan, miten viennin kysyntäsokit vaikuttavat suomalaisten teollisuusyritysten innovaatiotoimintaan. Analyysissa hyödynnetään korkeatasoisia aineistoja, kuten tullin yrityskohtaisia tietoja, patenttitoimintaa, prosessi- ja tuoteinnovaatioita sekä innovaatiopanoksia vuodesta 1999 alkaen. Tulosten mukaan positiiviset kysyntäsokit vaikuttavat myönteisesti patentointiin ja tuoteinnovaatioihin, kun taas negatiiviset sokit vähentävät patentointia ja vientiä. Tutkimuksen mukaan vaikutukset ovat dynaamisia: patenttihakemukset kasvavat lyhyellä aikavälillä, kun taas myönnetyt patentit toteutuvat pidemmillä aikaväleillä. Vientiyritysten välillä löytyy myös eroavaisuuksia. Positiivisia innovaatiovaikutuksia havaitaan pelkästään tuottavuuden eturintamassa olevissa, sekä taloudellisesti vahvemmissa yrityksissä. Tulokset viittaavat siihen, että taloudelliset rajoitteet voivat vaimentaa yritysten innovaatiotoimintaa ulkomaan kysynnän kasvusta huolimatta.

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Asiasanat: Kysynnän vientisokki, Yritystason analyysi, Innovaatiot, Teollisuus

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1. Introduction

Innovation is a key driver of economic growth and firm performance. Understanding the factors that influence innovation at the firm level is crucial for policymakers and business leaders. One potential source of innovation that has attracted increasing attention is international trade, with concurrent expansions observed for both global trade and innovation (Geng and Kali, 2021). Within the framework of incumbent exporters, changes in export demand operate through several mechanisms that are distinct from export-entry effects.[1] First, changes in foreign demand alter the expected returns to innovation by expanding or contracting the effective market size faced by incumbent exporters**.** Second, export demand expansions may intensify competitive pressure in foreign markets, even as aggregate demand rises. This competition effect arises because growing markets attract entry by new exporters and induce incumbent exporters to scale up, increasing rivalry within export destinations (e.g., Aghion et al., 2024). As a result, firms may innovate strategically to defend market share, differentiate products, or escape competition. Third, export demand shocks affect firms' cash flow and financial constraints, which in turn may shape their ability to innovate (e.g., Foellmi et al., 2021). This financial channel may interact with both the market size and competition effects, amplifying heterogeneity in innovation responses. This paper focuses on Finnish domestic firms and examines how changes in export demand influence their innovation decisions, contributing new evidence on this important policy issue.

[1] According to Melitz-type framework (Melitz, 2003), more productive and innovative firms self-select into exporting.

I analyze unique administrative data on Finnish manufacturing firms from 1999 onwards, combining financial records, customs data, and detailed information on various innovation measures. The empirical strategy exploits exogenous variation in firm-level export demand shocks, constructed using changes in product-specific imports to destination countries from the world market. This approach allows us to estimate the causal effects of export expansion or contraction on innovation activity. The study contributes to the literature by providing new evidence on how trade shocks impact firm-level innovation activity in the context of an advanced economy. Second, this study examines multiple innovation measures - beyond just patenting or process and product innovations - including both innovation outputs as well as innovation inputs, enabling a more comprehensive assessment of innovation impacts. Third, the study explores heterogeneous effects based on firm characteristics such as financial strength and productivity level. This reveals important nuances in how firms respond to trade shocks.

This paper relates to several strands of the literature. First, it builds on the growing body of firm-level research examining the link between trade and innovation. While innovation is an important factor for export activities[2], the relationship between innovation and exporting also operates in the opposite direction. Recent studies have sought to establish causal effects, showing that firms respond positively to improved access to export markets by introducing more product innovations (Liu and Buck, 2007; Lileeva and Trefler, 2010; Bratti and Felice, 2012), process innovations (Damijan et al. 2010), or both (Bustos, 2011; Fassio, 2017).[3] In contrast, Monreal-Pérez et al. (2012) find no evidence that exporting induces firms to develop

[2] See, for example, Lachenmaier and Woessman (2006), Cassimann et al. (2010), López-Bazo and Motellón (2018), and Elliott et al. (2020).

[3] See also a review of literature on the trade-innovation nexus, focusing two common types of technological innovation: process and product innovations (Geng and Kali, 2021).

such innovation activities. Other studies document a positive association between increased export opportunities and patenting activity (Salomon and Shaver, 2005; Coelli et al., 2022), R&D propensity (Yang, 2018), and investments in technology (Bustos, 2011).[4] This paper also relates indirectly to the literature on trade competition and innovation. Autor et al. (2020) show that rising import exposure reduces U.S. patent production and R&D expenditure. Kang (2025) distinguishes between import and export competition shocks from China and shows that export competition, in particular, increases South Korean firms' patenting activity.

The paper most closely related to this study is Aghion et al. (2024), who develop a product- and destination-specific export demand shock measure to evaluate the impact of demand conditions on firms' innovation decisions. They find that firms respond to export demand shocks by increasing patenting activity, an effect driven primarily by initially more productive firms. The results of this study are consistent with previous evidence, showing that expanding trade markets stimuate patenting activity. As expected, these innovation responses are dynamic, with patent applications rising in the short run and granted patents materializing only over longer horizons. In line with Aghion et al. (2024), patenting activity is increased only among more productive firms. In addition, the findings show that while process innovations respond in the short run, firms adjust to sustained changes in export demand by introducing new product innovations in the long run, thereby adding new evidence to the existing literature.

[4] Another strand of literature examines the relationship between exporting and productivity, and product scope and quality more broadly (for a survey, see Shu and Steinwender, 2019). Although interesting, this paper concentrates on core innovation outcomes, which directly measure firms' inventive activities.

The results can also be related to the broader literature on the cyclicality of innovations. According to the opportunity cost hypothesis, growth-enhancing innovation activities should be concentrated during economic downturns rather than upturns (Aghion and Saint-Paul, 1998).[5] Nevertheless, a large body of empirical evidence documents that innovation activities tend to be procyclical (Armand and Mendi 2018; Barlevy 2007; Ma and Zimmermann 2023; Ouyang 2011; Silvestri et al. 2018), although some prior studies provide support for the opportunity cost hypothesis (Aghion et al., 2012). The results of this paper show that firms increase patenting activity and the introduction of new product innovations during positive export demand phases, while patenting declines during negative phases. These findings are broadly consistent with the procyclicality of innovation documented in the literature.

Our results should also be contrasted with the literature examining how financial constraints and economic shocks influence firms' performance. Foellmi et al. (2021) contribute to the trade-innovation literature by incorporating credit constraints into their model. They show that while tariff reductions – i.e., improved access to export markets – slightly increase R&D-related activities, these effects become negative for credit-constrained firms. Their findings highlight how limited access to finance affects firms' decisions to invest in innovative activities. More broadly, this literature emphasizes the role of credit constraints over different economic phases of the firm cycle, showing that tightened credit conditions during downturns - such as periods of export contraction - can impede firms' innovation activities (Ouyang, 2011; Aghion et al., 2012; Ma and Zimmermann, 2023). The results of this paper provide clear evidence that the

[5] Export demand shocks can be interpreted as firm-level exposure to international business cycle fluctuations, with negative shocks resembling foreign-market downturns and positive shocks capturing upturns that expand opportunities but may also intensify competition.

innovation response to trade shocks depends on firms' financial constraints. Specifically, only firms with stronger financial positions are able to translate expanding trade markets into enhanced innovation activity, whereas financially weaker firms experience declines in exports, sales, and patenting in response to trade shocks. This pattern suggests that financial constraints limit firms' ability to adopt and sustain innovation, even when export opportunities expand.

The remainder of the paper is structured as follows. Sections 2 and 3 describe the empirical strategy and the data used in the analysis, respectively. Section 4 presents and discusses the results, and Section 5 concludes by summarizing the main findings.

2. Empirical Estimation Strategy

2.1. Firm-level Export Demand Shocks

To identify the causal effect of export demand shocks on a firm's innovation activity, the empirical strategy follows the approach developed by Aghion et al. (2024) to derive an exogenous firm-level measure of export demand shocks. In this framework, changes in global import demand for products s in destination countries j (excluding Finland) between period t_0 and t are used to construct a proxy for the export opportunities faced by Finnish firm f. The firm-level shock measure is obtained by weighting these destination-product import changes by the firm's initial export structure, that is, by the shares of each product-destination pair in its export portfolio at time t_0.

Formally, consider a firm f exporting product s to destination j in the base year t_0. Let $M_{j,s,t}$ denote aggregate imports of product s by country j from all origins except Finland in year $t > t_0$. Excluding Finnish exports from the global import totals ensures that the resulting measure reflects changes in external demand rather than shocks originating from Finland itself. The firm-level measure of export demand is then obtained by summing $M_{j,s,t}$ values across all products and destinations, weighted by the relative importance of each product-destination (s, j) combination in firm f's exports at t_0. The resulting weighted index is subsequently multiplied by the firm's initial export intensity, defined as the share of exports in total sales at the beginning of the period. This scaling ensures that the magnitude of a trade shock is proportional to the firm's exposure to foreign markets relative to its overall production.

Let t_0 denote the first year of the observation period, restricting to firms with positive exports. Define $X_{f,j,s,t0}$ as f's export value to market (j, s) at time t_0. The firm-level export demand shock between t_0. and t is given by:

$$\Delta D_{f,t} = \sum_{j,s} w_{f,j,s,t_0} \frac{\Delta M_{j,s,t}}{\frac{1}{2}(M_{j,s,t} + M_{j,s,,t_0})} \tag{1}$$

where the weight $w_{f,j,s,t_0} \equiv \left(\frac{X_{f,t_0}}{S_{f,t_0}}\right)\left(\frac{X_{f,j,s,t_0}}{X_{f,t_0}}\right)$ represents firm f's initial share of sales accounted by product s (at the HS6 level) exported to destination market j. Here, $X_{f,,t_0} = \sum_{j,s} X_{f,j,s,t_0}$ denotes the firm's total exports and S_{f,t_0} its total sales in the base year. The exposure weights $w_{f,j,s,t0}$ do not necessarily sum to one, as they incorporate the firm's overall export intensity. Consequently, even firms with identical export portfolios may experience differing degrees of exposure depending on their initial reliance on exports.

This constructed measure of export demand shock follows the logic of a shift-share (Bartik-type) instrument (Bartik, 1991), where aggregate external shocks are combined with pre-determined firm-level exposure shares. Similar strategies, using destination-product specific import growth as a proxy for external demand or competition, have been applied in studies of offshoring and trade-induced adjustment (e.g., Hummels et al., 2014). In this setting, the time variation in $\Delta D_{f,t}$ originates exclusively from the evolution of world import flows $M_{j,s,t}$, while firm-specific weights remain fixed at their initial-year values.

2.2. Estimation Models

The analysis is conducted using a first-differences specification. Estimating the model in differences helps remove potential bias arising from any correlation between time-invariant firm characteristics and the level of export demand $D_{f,t}$. The likelihood that such unobserved characteristics correlate with changes in export demand is considerably lower than for demand levels.[6]

The baseline specification examines the impact of export demand shock on innovation activity as follows:

$$\Delta \mathrm{Y}_{\mathrm{f,t}} = \beta_1 \Delta \mathrm{D}_{\mathrm{f,t}} + \vartheta'(Z_{f,t0} \times \Upsilon_t) + e_{f,t} \tag{2}$$

[6] Aghion et al. (2024) show that firm characteristics correlate with demand *levels* but not with *changes* in demand. Likewise, Borusyak et al. (2022) and Goldsmith-Pinkham et al. (2020) note that any residual bias diminishes as the number of destination–product shocks increases, supporting the use of first differences.

where $\Delta Y_{f,t}$ denotes the change in firm-level innovation activity and $\Delta D_{f,t}$ is the export demand shock defined in Equation (1). The model is incorporated by a vector of initial firm-level controls (industry, firm size, and sales) for firm *f* at t_0, which are interacted with year fixed effects Υ_t. This specification addresses the concern that, for example, trends in the growth of firm size may be confounded with changes in demand. Standard errors are clustered at the industry level.

Accordingly, because aggregate demand shocks ($\Delta D_{f,t}$) may mask differences between positive and negative shocks, the empirical analysis further distinguishes their effects by sign. To examine how positive and negative export demand shocks influence firm-level innovation activity, the specification is expressed as:

$$\Delta \mathrm{Y}_{\mathrm{f,t}} = \beta_1 \Delta \mathrm{D}_{\mathrm{f,t}} I_{f,t}^{N} + \beta_2 \Delta \mathrm{D}_{\mathrm{f,t}} I_{f,t}^{P} + \vartheta'(Z_{f,t0} \times \Upsilon_t) + e_{f,t} \tag{3}$$

Here, $I_{f,t}^{N}$ equals one if firm *f* experienced a negative export demand shock and zero otherwise, whereas $I_{f,t}^{P}$ equals one for a positive shock and zero otherwise.

Firms require time to adjust production processes, explore innovation potential, or reallocate resources following external shocks (Aghion et al., 2024). To capture such dynamic responses, the observation period (1999–2022) is divided into five four to five-year subperiods**:** 1999–

2004, 2004–2009, 2009–2013, 2013–2018, and 2018–2022.[7] Computing first differences over these windows—using initial-year weights for the shock variable—allows the model to reflect longer-term adjustment. Notably, a firm may still experience a positive export shock even during periods of overall economic downturn, and vice versa.

Finally, the heterogenous impacts of trade shocks are examined, following Foellmi et al. (2021) and Aghion et al. (2024). Specifically, I will study whether the effect of export demand shock vary with firm's initial productivity and financial strength levels. To this end, the model incorporated interactions between the continuous shock measure $\Delta D_{f,t}$ and the indicator variables for firm's initial financial strength or productivity level (sales per employee) The initial financial strength is measured using the equity ratio[8] in the base year t_0. A firm is classified as being financially strong if its equity ratio is above the median within its respective 2-digit sector, and financially weak otherwise. A similar approach is used for labor productivity, using indicators for above and below median labor productivity within 2-digit sector, defined as P^{H}_{f,t_0} and P^{L}_{f,t_0}. The estimation model, incorporating these heterogeneous effects, is specified as follows:

[7] Note, however, that the length of the innovation data varies across variables, with the shortest series covering patenting activity (1999–2013) and the longest covering the innovation and R&D surveys (1999–2022). The characteristics of these datasets are discussed in the following sections.

[8] Since credit constraints are often not directly observable, indirect measures such as liquidity and leverage derived from financial statements are commonly used to proxy the likelihood of a firm facing credit constraints (e.g., Wagner, 2014 for a survey). In this analysis, I use the equity ratio (an inverse of leverage) to represent the firm's equity relative to total assets, a measure suitable to detect a firm's financial capacity at the long term.

$$\Delta \mathrm{Y}_{\mathrm{f,t}} = \beta_1 \Delta \mathrm{D}_{\mathrm{f,t}} P^{H}_{f,t_0} + \beta_2 \Delta \mathrm{D}_{\mathrm{f,t}} P^{L}_{f,t_0} + P^{H}_{f,t_0} + \vartheta'(Z_{f,t0} \times \Upsilon_t) + e_{f,t} \quad (4)$$

Since the firm's initial financial strength level or productivity level is used to construct the two different trade shocks, these variables are included in equation (4).

When estimating Equations (2) to (4) across the full sample period, the differenced observations for the different subperiods are stacked (e.g., Autor et al., 2013), and each period is represented by its own time indicator (γ_t). Since the model is expressed in first differences, the period-specific regressions are equivalent to fixed-effects estimations. The stacked specification, in turn, corresponds to a five-period fixed-effects framework, but with slightly less restrictive assumptions concerning the structure of the error term.

3. Data Construction and Definitions

3.1. Data Sources

The analysis draws on several administrative data sources provided by Statistics Finland. The core dataset is the Financial Statement Panel, which contains detailed profit-and-loss accounts and balance sheet information for Finnish firms. Key variables are harmonized over time, enabling consistent comparisons across years. The panel includes all independent business enterprises from 1986 onward. Enterprises employing at least 20 persons are included through direct data collection, while information on smaller and non-respondent firms is obtained from administrative registers. The dataset records firm-level characteristics including industry classification, number of employees, sales, and various financial indicators.

An exogenous export demand shock variable is constructed using two complementary data sources: the UN Comtrade database and Finnish firm-level customs records. The Comtrade database provides comprehensive bilateral trade statistics, covering exports and imports between all country pairs at the six-digit HS2002 product level. For each product–destination combination, the Comtrade data are combined with Finnish customs data to determine total global imports as well as imports originating from Finland. The customs records, available from 1999 onward, contain firm-level information on both export and import flows, including trade values with all partner countries. Goods are originally classified at the eight-digit Combined Nomenclature (CN) level and subsequently aggregated to the six-digit HS2002 level for consistency with Comtrade.

Data on firms' innovation outcomes are obtained from several complementary sources. Patent information is drawn from the Finnish Patent and Registration Office (PRH)**,** covering patents granted during 1995–2013 and patent applications from 1985–2013. Additional indicators of innovation performance are drawn from the Innovation Survey, conducted biennially between 2000 and 2022, covering approximately 2,500 firms per wave.

Information on research and development activities is derived from the firm-level R&D surveys, available annually since 1989. These surveys are compiled by Statistics Finland using data reported by companies, higher education institutions, major hospitals, and public research organizations. They target firms likely to engage in R&D, including all previously active R&D performers, large firms (over 100 employees), firms receiving government R&D support or tax incentives, and a random sample of medium-sized enterprises (10–100 employees). The survey typically includes about 4,000 firms per year, with response rates between 75% and 78%, and provides detailed information on R&D expenditures and activities.

Finally, information on employee characteristics is obtained from the FOLK registers of Statistics Finland, which cover the entire Finnish population between 1999 and 2018. Crucially for this study, these registers provide detailed data on individuals' occupations, and employment relationships, enabling the linkage of worker attributes to their employing enterprises.

3.2. Innovation Measures

Innovation output is first measured using two continuous variables reflecting the number of patent applications or the number of granted patents of a firm in a given year. Additional variables for innovation are derived from survey data identifying whether firms engaged in process or product innovation during the previous two years, determined by indicator outcomes. Because the Innovation Survey is conducted biennially, missing data for intervening years are imputed using values from the subsequent year.

While innovation outputs capture the tangible results of the innovation process, innovation inputs represent the resources and efforts invested in generating those outcomes. Differentiating between innovation outputs and innovation inputs provides additional insight into whether external trade shocks influence innovation directly or through firms' resource allocation. In this study, these resources are captured by internal R&D expenditures (in euros), sourced from the

R&D survey.[9] The analysis is subjected to robustness analysis using alternative innovation measures.

3.3. Sample Construction and Description of the Firm Samples

The analysis focuses on firms that were exporters with at least 10 employees in the initial year and operating in the manufacturing sector. Firms in this sector are classified according to the Standard Industrial Classification (SIC 2002), the SIC codes 15-37. Furthermore, the sample is restricted to innovative firms, defined as those that reported some patenting activity between 1985 and the year preceding each period's initial year. The final dataset was cleaned to address missing values and outliers.

The full estimation period spans from 1999 to 2022. The Customs data cover all firms and provide the largest number of observations for the five-period stacked model, comprising 3,218 observations from 1,138 firms. Patent data from 1999 to 2013 constitute a census of patent applications and granted patens registered by the Finnish Patent and Registration Office. Firms absent from this dataset are not engaged in patent activity. The patent data include 1,839 firm-year observations, with an average of 0.7 patent applications and 0.5 granted patents per firm-year. The Innovation survey is the smallest dataset, consisting of approximately 800 firm-year observations; among these firms, around 60-70% of exporters reported engaging in process or

[9] R&D expenditure is often used as a proxy variable for innovation activity, although it should be viewed as an input to innovation rather than an output (Lerner and Seru, 2022).

product innovations in the previous two years. The R&D survey includes 1,644 firm-year observations, with average internal R&D expenditures of approximately 6.5 million euros.

4. Econometric Results

4.1. Baseline Results

Table 1 presents the regression results for various measures of innovation outcomes. As additional outcomes, the table also documents the impact of the export demand shock on total exports (in euros), the likelihood of exiting export markets, and sales, which serve as important benchmarks for assessing the broader effects of trade shocks. Panel A reports results from the baseline specification (Equation 2). I find that the export demand shocks are positively associated with exports and sales; however, the coefficients are statistically insignificant, as shown in Columns 1 and 3 of Panel A. Expanding markets also reduce the likelihood that a firm exits export markets. However, export demand shocks do not appear to affect firms' innovation inputs. For example, although the estimated effect on internal R&D expenditure is positive, it is not statistically significance at conventional levels (Column 8 of Panel A). Export demand shocks positively influence the implementation of new product innovations but do not increase process innovations ($\beta = 0.205$, $p < 0.100$). Finally, Column 5 of Panel A shows a positive and statistically significant effect of the export demand shock on the number of granted patents ($\beta = 0.963$, $p < 0.050$). Specifically, Finnish firms exposed to an export demand shock equivalent to one standard deviation of the shock variable experience an increase of approximately 0.20 granted patents, as well as an increase of about 4 percentage points in the likelihood of introducing new product innovations.

Panel B of Table 1 reports the regression results from Equation (3), which distinguishes negative and positive export demand shocks. The findings indicate that negative shocks reduce total exports and sales, whereas positive shocks yield statistically insignificant coefficients for these outcomes. I also find that firms increase patenting activity when export markets expand, while patenting activity declines when trade markets contract (Column 5 of Panel B). The effect of a negative shock is particularly economically significant, as a one-standard-deviation increase in the negative shock variable is associated with a reduction of approximately 0.7 granted patents. Firms also tend to introduce new product innovations during positive demand phases ($\beta = 0.287$, $p < 0.100$), but do not reduce such innovations during negative phases.

[Add Table 1 in here]

4.2. Robustness Tests

The results on the effect of export demand shocks on innovation are subjected to a range of robustness and sensitivity checks, including the use of alternative measures and estimation samples. First, alternative measures of innovation activity are employed to assess the sensitivity of the results, beginning with binary variables capturing patenting activity at the extensive margins. These outcomes indicate whether a firm has any patent applications or granted patents in a given year. In addition, key innovation inputs relate to firms' human capital, defined by the skills and expertise of employees engaged in innovation-related tasks. The analysis is therefore complemented with two human-capital measures: the number of STEM workers and the number of R&D personnel, capturing the stock of employees directly involved in research, development, and technological activities. The number of R&D personnel is obtained from the R&D survey, while STEM workers are identified as employees in ISCO 2-digit occupations

21, 25, 31, and 35 (e.g., Meoli et al., 2024). Finally, two additional alternative measures of innovation activity are considered using administrative data on external R&D expenditures and revenues from patents and licenses from the Longitudinal Database on Plants in Finnish Manufacturing for the period 1999-2018.

The results, presented in Table A1 of the Appendix, are broadly consistent with the main findings. Specifically, the coefficient linking export demand shocks to any patenting is statistically significant at the conventional levels ($\beta = 0.086$, $p < 0.100$). By contrast, export demand shocks are not significantly associated with external R&D expenditure, consistent with results obtained from a smaller sample of self-reported survey data. Moreover, the point estimates for the number of research workers are not statistically different from zero, providing further support for the absence of a significant relationship between trade shocks and innovation inputs.[10]

Second, a short-term adjustment is examined using differences over two-year periods (1999-2001, 2001-2003, etc.). The results, reported in Panel A of Table 2, suggest that export demand shocks increase firms' innovation activities through introduction of new process innovations, while no statistically significant effects are observed for product innovations, contrasting with the longer-term effects. The results also show a statistically significant effect on patent applications ($\beta = 0.500$, $p < 0.050$), but not for the number of granted patents. Export demand

[10] A comprehensive series of other sensitivity checks validate the robustness of the results (not reported in tables). These tests include omitting all control variables except year and industry indicators, and clustering of standard errors at the firm level. The results also remain robust to excluding the electronics sector, indicating that the effects are not driven by the "rise and fall of Nokia".

shocks may thus create immediate incentives for firms to protect and commercialize new ideas, leading to a short-run increase in patent applications**.** In contrast, granted patents materialize only in the long run, reflecting the lengthy and uncertain patent examination process.

Third, the sample is extended to include all exporting firms, rather than being restricted to innovative firms only. This exercise allows the analysis to capture the effects of trade shocks at the extensive margin as well.[11] The results show that the effects on both patenting and product innovations become statistically insignificant (Panel B of Table 2). These findings suggest that only initially innovative firms tend to benefit from expanding trade markets, highlighting that adjustment occurs primarily at the intensive margin.

[Add Table 2 in here]

4.3. Heterogeneity Analyses

The results from the stacked first-differences model, with effects differentiated by firms' productivity level, are presented in Panel A of Table 3. While the baseline results indicated no statistically significant impact of export demand shocks on total exports, Panel A reveals positive and statistically significant effects for more productive firms. Furthermore, Column 5 shows that export demand shocks increase the number of granted patents among more productive firms ($\beta = 2.274$, $p < 0.100$), an effect that is not observed among less productive firms. Firms' sales also respond positively to expanding trade markets, with the effect being statistically significant only for more productive firms (Column 3 of Panel A).

[11] In this specification, firms' initial patenting activity is controlled for in the estimations.

Panel B of Table 3 documents heterogenous effects by firms' initial financial strength. The results for total exports, sales, and the number of granted patents closely resemble those by productivity level, partly reflecting that firms operating at the productivity frontier also tend to have stronger financial positions (e.g., Foster et al., 2008). In addition, financially stronger firms – but not financially weaker ones – experience a reduced risk of exiting export markets following an export demand shock (Column 2 of Panel B). I also find that the likelihood of introducing new product innovations increases only among financially stronger firms, while no such effect is found for financially weaker firms. By contrast, the introduction of process innovations declines among financially weaker firms.

[Add Table 3 in here]

5. Discussion

This study provides evidence that firm-level export demand shocks significantly influence innovation activities in the Finnish manufacturing sector. The results demonstrate that positive export demand shocks increase firms' patenting activity and the likelihood of introducing new product innovations, while negative shocks reduce patenting and exports. The findings highlight the dynamic nature of innovation responses, with patent applications rising promptly following demand expansions and granted patents materializing only over longer horizons due to patent examination lags. These results are consistent with previous evidence documenting that firms respond positively to improved access to export markets by introducing more product innovations (Liu and Buck, 2007; Lileeva and Trefler, 2010; Bratti and Felice, 2012) and by increasing patent activity (Salomon and Shaver, 2005; Coelli et al., 2022; Aghion et al., 2024).

Moreover, the study reveals substantial heterogeneity in these effects: more productive and financially stronger firms benefit disproportionately from export demand expansions in terms of innovation output and sales growth (Foellmi et al., 2021; Aghion et al., 2024). Contrary to some prior studies (e.g., Yang, 2018; Autor et al., 2020), changes in trade markets do not have a statistically significant effect on R&D spending, suggesting that innovation inputs may be less sensitive to trade shocks or that firms reallocate resources efficiently. The absence of a clear link between export demand shocks and R&D inputs also implies that firms may rely on alternative mechanisms - such as process improvements and product development - to respond to changes in export opportunities. However, the results indicate that only innovative firms tend to benefit from expanding trade markets, suggesting that adjustment occurs primarily at the intensive margin rather than at the extensive margin.

The findings further suggest that policies aimed at fostering innovative firms' access to foreign markets can stimulate more innovation, particularly in product development and patenting. Trade facilitation, the reduction of export barriers, and the promotion of international market integration should therefore be prioritized to strengthen firms' innovation incentives. At the same time, targeted assistance for less productive and financially constrained firms is needed. Since more productive and financially stronger firms derive greater innovation benefits from export demand shocks, targeted financial support and capacity-building programs could help less productive or financially weaker firms overcome constraints and better capitalize on export opportunities.

Finally, monitoring and supporting innovation during export downturns is also important. Because negative export demand shocks reduce patenting and exports, countercyclical innovation policies – such innovation grants or tax incentives during downturns – may help firms maintain innovation momentum during adverse trade conditions. Implementing such policy measures can enhance the innovative capacity of manufacturing firms, enabling them to better leverage global trade dynamics for sustained growth and competitiveness.

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Table 1. The effect of export demand shock on innovation measures and other firm-level outcomes

	Exports (1)	Exit exporting (2)	Sales (3)	Patent applications (4)	Granted patents (5)	Process innovation (6)	Product innovation (7)	Internal R&D expenditure (8)
Panel A: Effect of export demand shock								
Export shock	0.285	-0.075**	0.130	1.174	0.963**	-0.083	0.205*	0.428
	(0.3121)	(0.0302)	(0.0844)	(0.7058)	(0.3761)	(0.0883)	(0.0919)	(0.6692)
Obs.	3,218	3,218	3,170	1,839	1,839	798	798	1,644
R^2	0.038	0.044	0.044	0.020	0.032	0.057	0.086	0.040
Panel B: Effects of negative and positive export demand shocks								
Negative shock	1.329*	0.177**	0.587***	3.301	3.844**	-0.162	-0.349	2.841
	(0.6620)	(0.0563)	(0.1187)	(2.316)	(1.455)	(0.4829)	(0.2042)	(1.535)
Positive shock	0.203	-0.095**	0.095	0.866	0.545*	-0.071	0.287*	0.071
	(0.3549)	(0.0398)	(0.0789)	(0.6685)	(0.2809)	(0.1311)	(0.1293)	(0.7193)
Obs.	3,218	3,218	3,170	1,839	1,839	798	798	1,644
R^2	0.039	0.048	0.045	0.021	0.035	0.057	0.090	0.041
Std.dev(shock)	0.238	0.238	0.238	0.179	0.179	0.204	0.204	0.201

Notes: Exports, sales and internal R&D expenditure (in euros) are in logarithms; patent applications and granted patents are count variables; and process and product innovations are indicator variables. Each outcome is then expressed as differences between initial and end year. Negative shock refers to situation where the export demand is decreasing, whereas positive shock refers to the situation where the export demand is increasing. Other controls include interactions between industry, initial firm size (number of employees), and initial sales with year indicators. Models are estimated using stacked first difference estimation, using five sub-periods. Standard errors (in parentheses) are clustered at industry level. *** $p<0.010$, ** $p<0.050$, * $p<0.100$.

Table 2. The effect of export demand shock on innovation measures and other firm-level outcomes

	Exports (1)	Exit exporting (2)	Sales (3)	Patent applications (4)	Granted patents (5)	Process innovation (6)	Product innovation (7)	Internal R&D expenditure (8)
Panel A: Effect of export demand shock, two-year differences								
Export shock	0.325	-0.022	0.147	0.500**	-0.153	0.084*	0.038	-0.059
	(0.2160)	(0.0162)	(0.0829)	(0.1853)	(0.2432)	(0.0387)	(0.0214)	(0.5287)
Obs.	8,760	8,760	8,681	4,702	4,702	1,796	1,796	4,609
R^2	0.039	0.134	0.059	0.038	0.040	0.109	0.243	0.028
Std.dev(shock)	0.187	0.187	0.187	0.163	0.163	0.259	0.259	0.158
Panel B: Effects of export demand shock, including all exporters								
Export shock	0.138	-0.032	0.127***	0.069	0.054	0.0114	0.111	0.269
	(0.1195)	(0.023)	(0.0132)	(0.0806)	(0.0595)	(0.0584)	(0.0601)	(0.3384)
Obs.	8,517	8,517	8,414	4,983	4,983	1,490	1,490	2,801
R^2	0.066	0.077	0.040	0.011	0.020	0.035	0.037	0.028
Std.dev(shock)	0.397	0.397	0.397	0.470	0.470	0.201	0.201	0.213

Notes: Exports, sales and internal R&D expenditure (in euros) are in logarithms; patent applications and granted patents are count variables; and process and product innovations are indicator variables. Each outcome is then expressed as differences between initial and end year. Other controls include interactions between industry, initial firm size (number of employees), and initial sales with year indicators. Panel B also controls for the past patenting activity. Models are estimated using stacked first difference estimation, using 12 (Panel A) or five (Panel B) sub-periods. Standard errors (in parentheses) are clustered at industry level. *** p<0.010, ** p<0.050, * p<0.100.

Table 3. The effect of export demand shock by firm's initial productivity and financial strength levels

	Exports (1)	Exit exporting (2)	Sales (3)	Patent applications (4)	Granted patents (5)	Process innovation (6)	Product innovation (7)	Internal R&D expenditure (8)
Panel A: The effect of export demand shock by productivity level								
Shock x Low	0.096	-0.059*	0.095	0.284	0.157	-0.082	0.188	0.804
	(0.2967)	(0.0289)	(0.0776)	(0.1676)	(0.1439)	(0.1315)	(0.1350)	(1.190)
Shock x High	0.849***	-0.120***	0.242**	2.686	2.274*	-0.064	0.196	0.169
	(0.2118)	(0.0203)	(0.0722)	(1.746)	(1.015)	(0.1199)	(0.1314)	(0.8011)
F-test β_1=β_2	3.55*	3.35	6.71**	1.89	3.49*	0.01	0.00	0.23
Obs.	3,218	3,218	3,170	1,839	1,839	798	798	1,644
R^2	0.039	0.046	0.045	0.017	0.036	0.057	0.089	0.040
Panel B: The effect of export demand shock by financial strength								
Shock x Low	0.285	-0.079	0.019	0.204	0.730	-0.370***	0.134	0.873
	(0.3180)	(0.0465)	(0.0638)	(0.4370)	(0.4706)	(0.0778)	(0.1879)	(1.110)
Shock x High	0.618*	-0.077***	0.186**	2.221	1.439**	0.029	0.222*	-0.071
	(0.3144)	(0.0155)	(0.0703)	(1.121)	(0.4889)	(0.1139)	(0.0969)	(0.4529)
F-test β_1=β_2	0.78	0.00	4.13*	5.03*	1.98	8.17**	0.17	1.00
Obs.	3,218	3,218	3,170	1,839	1,839	798	798	1,644
R^2	0.041	0.050	0.044	0.022	0.034	0.062	0.085	0.041
Std.dev(shock)	0.238	0.238	0.238	0.179	0.179	0.204	0.204	0.201

Notes: Exports, sales and internal R&D expenditure (in euros) are in logarithms; patent applications and granted patents are count variables; and process and product innovations are indicator variables. Each outcome is then expressed as differences between initial and end year. Low (high) indicates that the labor productivity (Panel A) or equity ratio (Panel B) is below (above) the median value within the 2-digit sector where the firm operates. Other controls include interactions between industry, initial firm size (number of employees), and initial sales with year indicators; and an indicator variable for high/low productivity (Panel A) or financial strength (Panel B) levels. Models are estimated using stacked first difference estimation, using five sub-periods. *F*-tests for equal coefficient estimates for the two shock variables. Standard errors (in parentheses) are clustered at industry level. *** p<0.010, ** p<0.050, * p<0.100.

Appendix

Table A1. The effect of export demand shock on innovation activity, alternative measures

	Having any patent applications (1)	Having any granted patents (2)	Number of R&D workers (3)	Number of STEM workers (4)	External R&D expenses (5)	Revenues from patents (6)
Shock	0.086*	-0.042	22.129	11.012	-0.909	0.066
	(0.0471)	(0.0351)	(21.767)	(9.431)	(0.8161)	(0.2827)
Obs.	1,839	1,839	1,644	2,546	2,847	2,679
R^2	0.017	0.041	0.040	0.023	0.054	0.085
Std.dev(shock)	0.179	0.179	0.201	0.173	0.247	0.250

Notes: Having and patent applications or granted patents are indicator variabels; the number of R&D workers and STEM workers are count variables; and external R&D expenditure and revenues from patents and licenses (in euros) are in logarithms. Each outcome is then expressed as differences between initial and end year. Other controls include interactions between industry, initial firm size (number of employees), and initial sales with year indicators. Models are estimated using stacked first difference estimation, using five sub-periods. Standard errors (in parentheses) are clustered at industry level. * p<0.100.

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