ETLA Working Papers | 132 25.8.2025

Export Demand Shocks and Environmental Performance

EVIDENCE FROM FINNISH EXPORTERS

Terhi Maczulskij
ETLA Economic Research, Finland
terhi.maczulskij@etla.fi

Outi Jurvanen
University of Helsinki and the Labour Institute for Economic Research LABORE, Finland
outi.jurvanen@labore.fi

Suggested citation:
Maczulskij, Terhi & Jurvanen, Outi (25.8.2025). "Export Demand Shocks and Environmental Performance: Evidence from Finnish Exporters". ETLA Working Papers No 132. https://pub.etla.fi/ETLA-Working-Papers-132.pdf

LABORE Working Papers 354
ISBN 978-952-209-227-4 (online publication)
ISSN 2984-2158

Abstract

This paper examines how firms' environmental performance responds to product- and destination-specific export demand shocks in their export markets. We draw on unique administrative data for Finnish manufacturing firms from 1999 to 2018, matched with national customs records, greenhouse gas emissions, and energy use. The results show that while export demand shocks significantly increase firms' export volumes and energy consumption, they do not improve overall environmental performance. Specifically, we find no significant effects on carbon intensity or total energy intensity, although fuel intensity declines, particularly in more polluting industries. Heterogeneity and mechanism analyses further reveal that financially weaker firms experience increases in emissions and carbon intensity, suggesting that financial constraints may limit their ability to adopt cleaner technologies. Overall, the findings highlight the critical role of firm-level characteristics in shaping the environmental consequences of trade shocks and suggest that export-promotion policies should account for firms' financial capacities to support green investments and sustainable outcomes.

Tiivistelmä

Viennin kysyntäsokin vaikutukset yritysten ympäristöhaittoihin Suomen vientiyrityksissä

Tässä tutkimuksessa on tarkasteltu viennin tuotekohtaisten kysyntäsokkien vaikutuksia vientiyritysten ympäristölliseen suorituskykyyn. Tutkimus on tehty hyödyntäen ainutlaatuista rekisteriaineostoa suomalaisista teollisuusyrityksistä vuosilta 1999–2018, joka on yhdistetty kansallisiin tullitilastoihin, kasvihuonekaasupäästöihin ja energiankulutustietoihin. Tulokset osoittavat, että positiiviset tuotekohtaiset kysyntäsokit lisäävät merkittävästi yritysten vientiä ja energiankulutusta, mutta eivät paranna kokonaisvaltaista ympäristösuorituskykyä hiili- tai energiaintensiteetillä mitattuna. Löydämme kuitenkin eroavaisuuksia erityyppisten yritysten välillä.

Esimerkiksi polttoaineintensiteetti laskee erityisesti saastuttavimmilla toimialoilla. Lisäksi havaitsemme, että taloudellisesti heikommassa asemassa olevien yritysten päästöt ja hiili-intensiteetti kasvavat, mikä viittaa siihen, että mahdolliset luotonsaantiin liittyvät ongelmat voivat rajoittaa yrityksiä investoimasta puhtaampaan teknologiaan. Tulokset korostavatkin tarvetta ymmärtää yrityskohtaisia eroja kauppasokkien ympäristövaikutuksissa. Erityisesti vientiä edistävissä politiikkatoimissa tulisi huomioida yritysten taloudelliset edellytykset kestävän kehityksen tukemiseksi.

Ph.D. **Terhi Maczulskij** is a Chief Research Scientist at ETLA Economic Research, a Research Director at the Yrjö Jahnsson Foundation and a Research Fellow at IZA.

M. Sc. **Outi Jurvanen** is a Post-doctoral Student at the University of Helsinki and Researcher at The Labour Institute for Economic Research LABORE.

KTT, FM, dosentti **Terhi Maczulskij** on Elinkeinoelämän tutkimuslaitoksen tutkimuspäällikkö, Yrjö Jahnssonin säätiön tutkimusjohtaja sekä IZA:n Research Fellow.

VTM **Outi Jurvanen** on Helsingin yliopiston jatko-opiskelija ja Työn ja talouden tutkimus LABOREn tutkija.

Acknowledgements: This paper is funded by the Confederation of Finnish Industry and Employers (TT) Foundation. We thank the participants at the Helsinki GSE macroeconomics seminar for their comments.

Kiitokset: Haluamme kiittää TT-säätiötä tutkimuksen rahoituksesta ja Helsinki GSE seminaariosallistujia hyödyllisistä kommenteista.

Keywords: Emissions, Energy expenditure, Energy intensity, Export demand shock, Firm-level, Carbon intensity

Asiasanat: Energiakustannukset, Energiaintensiteetti, Hiili-intensiteetti, Kysynnän vientisokki, Päästöt, Yritystason analyysi

JEL: D22, F22, O30

1 Introduction

The relationship between international trade and environmental performance has been a topic of significant interest in economics research. As firms expand their export activities, concerns arise about potential negative environmental impacts due to increased production and emissions. However, trade and greater production scale may also incentivize firms to adopt cleaner technologies and improve efficiency (Batrakova and Davies, 2012; Forslid et al., 2018). Additionally, firms entering export markets may be influenced by the regulatory and consumer preferences of importing countries, potentially fostering environmental innovation at home countries (Hanley and Semrau, 2022). This paper examines how export demand shocks affect the environmental performance of manufacturing firms, contributing new evidence on this important policy issue.

We analyze unique administrative data on Finnish manufacturing firms from 1999 to 2018, combining financial records, customs data, and detailed information on energy expenditure and emissions. Our 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 a range of environmental outcomes. Our study makes several contributions to the literature. First, we provide new evidence on how trade shocks impact firm-level environmental performance in the context of an advanced economy. Most existing research has focused on developing countries, where effects may differ due to technological gaps (Barrows and Ollivier, 2021). Second, we examine multiple environmental indicators beyond just emissions, including energy costs and intensity measures, enabling a more comprehensive assessment of environmental impacts. Third, we explore heterogeneous effects based on firm characteristics such as financial strength, initial pollution intensity, and the presence of environmentally conscious management and professional staff. This reveals important nuances in how firms respond to trade shocks. Environmental expertise in management, in particular, is likely to enhance firms' environmental performance through better strategic decision-making and the adoption of cleaner technologies. For example, Jung et al. (2021) find a positive link between firms' environmental performance and the environmental expertise of their management. This dimension has been overlooked in previous studies on the effects of export demand shocks, and our novel contribution is to integrate it into the literature.

Our analysis reveals several key findings. First, export demand shocks significantly increase firms' export volumes and energy costs, particularly electricity consumption. However, we find no evidence of improvements in overall environmental performance: there are no significant effects on carbon intensity or total energy intensity. In contrasts, fuel intensity declines in response to trade shocks, especially in more polluting industries, suggesting that firms may shift toward cleaner energy sources as they expand production. Importantly, we uncover substantial heterogeneity in environmental responses based on firm characteristics. Financially weaker firms experience increases in emissions and carbon intensity following export demand shocks, whereas financially stronger firms exhibit no such negative effects on the environment. Accordingly, energy expenditure increases among financially weaker firms but not in their financially stronger counterparts. This pattern, together with the mechanism analysis, suggests that financial constraints may limit the ability of firms to adopt cleaner technologies even as they expand production. We also find some evidence that firms with more environmentally-oriented management - measured by occupation-specific tasks - achieve larger reductions in carbon intensity. However, the result does not remain robust when using more precise measures based on the formal education in environmental fields of management and professional staff. We also find no convincing evidence that the observed linkages between trade shocks and environmental performance are driven by firms adjusting their production toward (potentially) cleaner and best-performing products.

Our paper relates to several strands of literature. First, it builds on a growing body of firm-level research examining trade-environment linkages. Early work documented that exporting firms tend to exhibit lower emissions intensity compared to non-exporters (Galdeano-

Gómez, 2010; Jinji and Sakamoto, 2015; Holladay, 2016; Forslid et al., 2018; Goldar and Goldar, 2023). [1] More recent studies have sought to establish causal effects, finding that exporting can lead to reductions in energy consumption and emissions intensity (Batrakova and Davies, 2012; Roy and Yasar, 2015; Tran, 2022).

This study explicitly examines the effect of export demand shocks, extending previous research in the area. [2] Barrows and Ollivier (2021) analyze the effect of foreign demand on CO_2 emissions in Indian firms using a shift-share instrument. They find that increased export demand raises emissions as the output increases, but reductions in emissions intensity – driven by technological adaption – partially offset the effect. Because firms in developing countries operate far from the technological frontier, the potential for technological upgrading is higher than in developed economies (Barrows and Ollivier, 2021). Wang et al. (2024) investigate the effect of foreign demand shock on SO_2 emissions in Chinese export firms. Focusing on multi-product firms and employing a Bartik instrument for changes in foreign demand, they find that increased demand shock reduces emissions intensity, yet the impact on the overall level of emissions is statistically insignificant. [3] The decline in emissions intensity is attributed to the reallocation of production toward cleaner products and the adoption of cleaner technologies. Similarly, Xie and Li (2024) use a shift-share design to study the impact of foreign demand shocks on emission intensity in Chinese firms. They document that such shocks lead to a reduction in emission intensity, with the effect being more profound for multi-product firms than for single-product firms. In contrast, Lehr (2025) examines the effects of export opportunities arising from the rise of Eastern Europe and China, using data on German manufacturing firms, and finds that exporting increased

[1] Melitz-type models highlight the endogenous link between emission intensity and export activity, as more productive firms tend to become exporters (Forslid et al., 2018).

[2] Another strand of literature examines the effects of import competition, typically finding that greater *import competition* leads to reduced emissions (Gutiérrez and Teshima, 2018) and to improvements in energy or emissions productivity (see, e.g. Gutiérrez and Teshima, 2018; Lehr, 2025). Such competition appears to reduce energy intensity primarily through improvements in production processes and the more efficient application of technologies (Feng and Wei, 2023).

[3] Another study from China focuses on city-level data instead of firm-level one. Wang (2021) used an import demand shocks of export destinations as an instrument and found that a rise in the city-level export shock led to an increased emissions but did not affect emission intensity in Chinese cities.

emissions, with only a small and negative impact on emissions intensity. [4]

This study also relates to the literature examining how financial constraints and economic shocks influence firms' environmental performance. Hong et al. (2012) find that firms facing fewer financial constraints tend to perform better in corporate social responsibility. Cohn and Deryugina (2018) analyze firms' exposure to exogenous cash flow shocks and show that stronger financial conditions are associated with fewer pollution incidents. Similarly, Levine et al. (2018) report that positive liquidity shocks improve local firms' credit conditions, leading to reduced pollution and greater environmental commitments. Goetz (2019) investigates U.S. firms' responses to unconventional monetary shocks, finding significant reductions in toxic chemical emissions alongside increased investments in emission-reduction activities. Xu and Kim (2022) also demonstrate the positive impact of improved financial conditions on environmental outcomes, while Mahapatra et al. (2021), using data from 77 firms in the Global 500 list, observe that emission reductions alone are not necessarily linked to improved financial performance.

Our results should also be contrasted in light of the literature on examining the relationship between exporting and environmental innovation. Hanley and Semrau (2022) find a positive correlation between exporter and the adoption of process-based environmental innovation in 14 Eastern European countries. Alike, Girma et al. (2008), using the UK Community Innovation Survey, show that exporters are more likely to report innovations with significant environmental effects, even after controlling for factors such as productivity, size and workforce skills. Aghion et al. (2024) find that firms respond to firm-level export demand shocks by patenting more, although this pattern is driven by the subset of initially more productive firms. More broadly, this literature relates to the cyclicality of innovations, potentially linking fluctuations in economic conditions to growth-enhancing activities such as the adoption of green technologies (e.g., Aghion et al., 2012; Barlevy, 2007; Ouyang, 2011).

The remainder of the paper is structured as follows: Sections 2 and 3 detail the empirical

[4] Cherniwchan (2017) studied the effects of NAFTA, finding that trade liberalization led to significant reduction in pollution in the US.

strategy and data used in the analysis, respectively. The results are discussed in Section 4, and Section 5 concludes by summarizing the main findings and outlining directions for future research.

2 Empirical estimation strategy

2.1 Firm-level export demand shocks

To assess the causal impact of export demand shocks on a firm's environmental performance, we adopt the methodology outlined by Aghion et al. (2024) to construct an exogenous, firm-level measure of export demand shocks. This approach involves using changes in the imports of products s to destination j from the world market (excluding Finland) between period t and the initial year t_0 to create a proxy variable for the export demand faced by firm f. The overall firm-level measure is constructed by weighting the imports of product s to destination j based on the shares of product- and destination-specific exports in the export portfolio of firm f at time t_0.

Formally, consider an exporter f that exports a product s to destination j at year t_0. We denote the aggregate import flow of product s into country j from all countries except Finland at time $t > t_0$ as $M_{j,s,t}$. By excluding the total exports from Finland to destination j, we aim to eliminate variations originating in the firm's home country that might be correlated with changes for the firm.

To obtain the firm-level measure, we sum the $M_{j,s,t}$ values across destinations j and products s, weighting them by the relative importance of each product-market (s, j) in firm f's exports at the initial date t_0. Finally, we multiply this weighted export demand measure by the firm's initial export intensity. This intensity is defined as the share of exports in the total production of firm f at t_0. This approach ensures that the impact of any export shock is proportionate to a firm's exports relative to its total production.

Let t_0 be the first year of the studied period, including all firms with positive exports.

Let X_{f,j,s,t_0} denote firm f's export flow to market (j,s) at time t_0. The export demand shock for firm f between the start and the end of the period is then constructed as:

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

where the weight $w_{f,j,s,t_0} \equiv (X_{f,t_0}/S_{f,t_0})(X_{f,j,s,t_0}/X_{f,t_0})$ represents firm f's initial share of the sales of product s, at the HS6 level, to destination j, $X_(f,t_0) \equiv \sum_(j,s)X_{f,j,s,t_0}$ represents the firm's total exports, and S_{f,t_0} represents the firm's total sales at start year t_0. Thus, the sum of exposure weights w_{f,j,s,t_0} across (s,j)'s is different from one since the weight also includes firm f's overall export intensity in total sales. This implies that firms with identical export portfolios may still have a different shock exposure depending on their export intensity.

The constructed demand shock resembles a standard shift-share or "Bartik' (Bartik, 1991), where aggregate shocks are combined with measures of shock exposure. Shift-share instruments measuring shock exposure by changes in destination-product-specific imports, as a proxy for export supply, have been used in previous studies analyzing offshoring and import competition (e.g., Hummels et al., 2014). We note that the time variation in our demand shock $\Delta D_{f,t}$ stems from the variation in the world export flow $M_{j,s,t}$ and not the firm-level weights, which are fixed at the start year of the period of analysis.

2.2 Estimation models

Next, we present our estimation model for studying the effect of export demand shock ($\Delta D_{f,t}$) on firm-level responses to environmental performance. Our specification is defined in first-differences, which potentially eliminates any bias generated by a correlation between non-time-varying firm characteristics and the level of the demand shock $\Delta D_{f,t}$ Aghion et al. (2024). [5] Our baseline estimation model is specified as:

[5]Borusyak et al. (2022) and Goldsmith-Pinkham et al. (2020) argue that, despite the presence of such a correlation between the firm characteristics and future demand shocks, the induced bias diminishes as the

$$\Delta Y_{f,t} = \beta_1 \Delta D_{f,t} + i_{t_0} + \Upsilon_t + \delta' X_{f,t_0} \times \Upsilon_t + \varepsilon_{f,t} \quad (2)$$

where $\Delta Y_{f,t}$ represents the change in firm-level environmental performance between the start and the end of the period. Further, $\Delta D_{f,t}$ is the export demand shock defined in equation 1, and i_{t_0} denotes industry fixed effects measured at start year t_0, comprising 9 indicators. [6] We split our sample period from 1999 to 2018 into two distinct periods: pre-financial crisis period (1999-2007), and to post-financial crisis periods (2008-2018). We note that the measure of export demand shocks is product- and firm-specific. This indicates that export demand shocks experienced by firms could be positive or negative, regardless of adverse or positive macroeconomic developments. When estimating equation 2 over the long interval from 1999 to 2018, we stack the first differences for the two periods, therefore also including a time indicator denoted by Υ_t. This stacked first difference estimation approach has been used, for example, by Autor et al. (2013). Since the model is estimated in first differences, the period-specific models are equivalent to fixed effects regressions, while the stacked first difference models resemble a two-period fixed effects model with slightly less restrictive assumptions made on the error term. Finally, we follow Aghion et al. (2024) and augment Equation 2 with interaction terms between initial (t_0) number of employees and sales and the annual trend in vector X_{f,t_0}. This addresses the concern that trends in the growth of firm size may be confounded with changes in demand.

The regression estimates for the overall demand shock could hide an important heterogeneity based on firm-level characteristics. Therefore, in addition to the direct effect of the export demand shocks on a firm's environmental performance, we add an interaction between the demand shock measure and the firm's initial financial strength or greenness based on the

number of shocks (represented by our combination of destination-product pairs) increases substantially.

[6] Manufacturing sector industry information is classified according to the Standard Industrial Classification, grouped into nine aggregate categories based on a 2-digit classification system. These categories encompass: food and beverage products; textile, apparel, and leather goods; wood, pulp, and paper items; chemical, rubber, and non-metallic products; metal products; machinery and equipment; electrical and optical equipment; transportation equipment; and furniture and recycling industries.

composition of the top management and professionals at the start year, or whether the firm operated in either dirty or clean industry. Our estimation model with heterogeneous effects is specified as:

$$\Delta Y_{f,t} = \beta_1 \Delta D_{f,t} I^L_{f,t_0} + \beta_2 \Delta D_{f,t} I^H_{f,t_0} + i_{t_0} + \Upsilon_t + \delta' X_{f,t_0} \times \Upsilon_t + \varepsilon_{f,t} \tag{3}$$

First, we construct an indicator variable I^L_{f,t_0} for all firms, which equals 1 if a firm's financial strength in the initial year t_0 is below the median (denoted as L for low) within its 2-digit industry sector, and 0 otherwise. Similarly, $I_(f, t_0)^H$ equals 1 if the firm's f financial strength at year t_0 is above the median (denoted as H for high) within the same sector, and 0 otherwise. Comparing a firm's financial strength to others within the same industry controls for differences in physical capital intensity as well as other industry-level differences. Second, we include interactions between a shock variable and indicator, where $I_(f, t_0)^L$ equals 1 if the share of firm's green top management and professional staff in the initial year t_0 is below the median (denoted as L for low) within its 2-digit industry sector, and 0 otherwise. Similarly, I^H_{f,t_0} equals 1 if the share of firm's green top management and professional staff at year t_0 is above the median (denoted as H for high) within the same sector, and 0 otherwise. Finally, we define firms as clean (low pollution level) or dirty (high pollution level) based on the industry-level pollution intensity constructed by Fan et al. (2025). Dirty (clean) firms are classified as those firms operating in sectors that fall below (above) the pollution intensity within the 2-digit sector.

3 Data and measures

3.1 Data sources

The analysis is based on various administrative registers from Statistics Finland. The key data are the Financial Statement panel data, which include firms' most essential profit and loss accounts and balance sheet data. Variables such as value added and other provisional variables are comparable over time. The data cover all independent business enterprises from 1986 onwards. Enterprises with at least 20 employees are included in the direct data collection, while the data of smaller enterprises and non-respondent enterprises are derived from administrative records. The data include characteristics such as industry, number of personnel, value added, sales, and equity ratio. We utilize the UN's Comtrade database and firm-level customs data source to measure an exogenous export demand shock variable. The Comtrade database is a comprehensive register of all export and import flows between country pairs and encompasses goods classifications at the 6-digit HS2002 level. The Comtrade data in connection to the customs data are used to determine for each good-reporting country pair the total imports from the world market and the imports from Finland. The customs datasets cover both the exports and imports of goods at the firm level from 1999. These data include the total values of imports and exports to/from all partner countries. The goods are categorized at the most detailed goods category (8-digit level) based on the CN (Combined Nomenclature), which we consequently aggregate to to the 6-digit product level.

Additionally, we acquired data on expenses (in euros) related to energy consumption (fuels and electricity) from the Longitudinal Database on Plants in Finnish Manufacturing. The dataset also incorporates firm-level greenhouse gas (GHG) emission information from Statistics Finland's National Greenhouse Gas Inventory. This inventory documents yearly GHG emissions and removals, offering a foundation for climate policy development and evaluation. The dataset covers the period from 1999 to 2019, encompassing carbon dioxide and GHG emissions measured in CO_2 equivalents. Statistics Finland acts as the official body responsible for managing GHG inventory submissions in Finland, in accordance with the United Nations Framework Convention on Climate Change, EU regulations, and the Kyoto Protocol. It's worth noting that the emissions data includes the entire Finnish manufacturing industry for larger emitting firms, thus providing representative findings for this sector.

To explore the potential mechanisms between export demand shocks and firm's environmental performance, we obtained data on firm's revenues from patents from the Longitudinal Database on Plants in Finnish Manufacturing, and additions of machinery and equipment from the Financial Statement panel. We also obtained information on whether the firm has implemented new process innovations from the Innovation survey, with data available biannually from 2000 to 2018, encompassing approximately 2,500 firms per year. Each survey elicits information for the previous two years, which allows us to construct panel from 1999 onwards. Firm-level R&D surveys, available from 1989 onwards, were also included. The surveys are primarily designed to target companies likely to engage in R&D activities, including roughly 4,000 companies annually, to obtain information such as internal R&D expenses at the firm level.

Finally, we used administrative FOLK registers from Statistics Finland, which cover the entire Finnish population from 1999 to 2018. Most importantly to our analysis, the data provide comprehensive information on the occupation and educational background of the employees, that we can link to their employing enterprises.

3.2 Environmental performance variables

As specified in equation 2, we analyze the effect of export demand shock on the environmental performance of the firm, using the following outcome variables: (i) carbon intensity, (ii) energy intensity, (iii) the level of emissions, and (iv) the level of energy expenditure. The concept of carbon intensity refers to the connection between economic output and environmental impact, particularly greenhouse gas (GHG) emissions. It is calculated by dividing a company's yearly GHG emissions by its value added (VA). A lower carbon intensity figure suggests that a company produces more economic value per unit of carbon emissions, indicating more efficient carbon utilization and a reduced environmental impact.

In line with established methodologies, we define energy intensity as the ratio of a company's total yearly energy expenditure on fuel and electricity (measured in euros) to its annual value added (VA). [7] A decrease in energy intensity in the economy indicates that economic growth is being achieved with a reduced environmental impact, signaling a transition toward a more sustainable economic model. Following Gutiérrez and Teshima (2018), we further disaggregate total energy efficiency into two components: electricity expenditure over value added and fuel expenditure over value added. Each outcome variable is measured as the difference in their logarithmic values between years t_0 and t.

3.3 Other metrics

To examine the heterogeneity in the associations based on firm's initial financial strength, or the firm's greenness, we define these variables accordingly. First, the most frequently used indicators of a company's financial health is the leverage ratio. [8] This ratio, commonly represented by the debt-to-equity ratio (see, e.g., Knudsen and Lopatin, 2023), assesses the extent of debt or the proportion of capital that comes from borrowed funds. In our study, we utilize the equity ratio to represent a firm's equity in relation to its total assets, which serves as an inverse measure of leverage. To evaluate a company's initial financial position, we employ indicator variables for the equity ratios at the first year (t_0), categorized as either below or above the sector-specific median values for these ratios.

We assess a firm's greenness based on the environmental orientation of its top management and professional staff. This metric offers a human capital-centered perspective on sustainability efforts, emphasizing how firms allocate resources toward environmental roles. It also highlights the extent to which a company's key personnel are engaged in environmentally sustainable activities and serves as a proxy for the firm's overall commitment to environmental goals. Therefore, we measure firm greenness using data on occupations. These occupations are classified as either green (environmentally friendly) or non-green (including

[7] The results remain virtually unaffected when we use energy efficiency or productivity, measured as the ratio of a firm's value added to its energy usage in kwh or energy expenditure as alternative outcomes. These results are available from the authors on request.

[8] Due to the difficulty in directly observing credit constraints, researchers often employ indirect measures derived from financial statements to estimate the probability of a firm experiencing such constraints (e.g., Wagner, 2014, for a survey).

polluting "brown" and neutral "gray" roles) based on the 4-digit level ISCO-08 classification system (International Standard Occupation Classification), as proposed by Scholl et al. (2023), and recently applied by Maczulskij (2024). Top management and professionals are identified according to the 1-digit level of the ISCO-08 (International Standard Occupation Classification), specifically categories 1 (managers), 2 (professionals), and 3 (technicians and associate professionals).

3.4 Variables describing potential mechanisms

Five variables are employed to assess a firm's innovation-related activities, that are all introduced in the model as first-differences: (i) a binary variable that signifies whether a firm has introduced any new processes that may indicate innovation in its production line, (ii) the logarithm of a firm's investments in machinery and equipment, serving as a proxy for investments in more advanced machinery, (iii) the logarithm of income from a firm's patents and licenses, acting as a proxy for patents, (iv) the logarithm of internal R&D expenditures (adjusted to 2015 prices using the cost-of-living index) to represent a firm's own investment in R&D, and (v) the number of STEM employees as a direct measure of the human resources allocated to innovation within the firm. STEM employees are identified as those with higher-degree level education in science, technology, engineering, or mathematics, according to ISCED educational classifications. Finally, we use product mix as a potential mechanism between export demand shocks and environmental performance. We use two measures to describe this product mix, namely the number of exported products and an indicator variable for single-product firms.

3.5 Sample construction and descriptives

Table 1 presents summary statistics for the variables across two periods (1999–2007 and 2008–2018), showing values for the start and end years. The analysis focuses on manufacturing firms that were exporters with at least 20 employees in the initial year. The final dataset has been cleaned for missing values and outliers. Specifically, we drop firms whose energy expenditures (disaggregated into electricity and fuel) fall below the 1st percentile or above the 99th percentile. The total number of observations for the stacked model is 1,804, comprising 923 firms in the first period and 881 in the second. [9] While the GHG data are representative of the entire Finnish manufacturing sector, they are available only for a smaller sample of emitting enterprises, yielding a substantially lower sample size (237 firms in total). Value added, sales, exports, and energy expenditures are reported in millions of euros at 2015 prices. The average firm in the sample has around 140 employees and generates between €34 million and €56 million in annual turnover. These figures peaked in 2008, with nearly 190 employees and annual sales of €94 million. Value added and total exports follow a similar trend. Emissions levels were relatively stable between 1999 and 2008, averaging approximately 0.095 million tons CO_2-equivalent, but declined to 0.057 million tons CO_2-equivalent by 2018. Both energy intensity and emissions intensity has increased over time. The equity ratio—reflecting the proportion of equity in total assets—averaged around 43% for Finnish manufacturing firms, showing an improving trend from 1999 to 2018. During the first period, 12% of firms exited exporting, compared with 7.3% in the second period. The largest sectors are wood, pulp and paper products, chemicals, metal products, and machinery and equipment, together accounting for roughly two-thirds of the manufacturing industry.

[Add Table 1 in here]

4 Results

4.1 Main estimation results

Table 2 presents the regression results for various measures of environmental outcomes. As an additional outcome, we also report the impact of the export demand shock on total exports

[9] We note that not all firms report both fuel and electricity costs, resulting in slightly different sample sizes when using disaggregated data.

(in euros), which serves as an important benchmark for assessing the broader effects of trade shocks. To examine the scale effect, we additionally report the impact of export demand shock on value added. Panel A reports results from the baseline specification (Equation 2). We find that the export demand shock has a positive and statistically significant effect on total exports ($\beta = 2.439, \mathrm{p} < 0.010$), as shown in Column 1 of Panel A. However, such export demand shocks do not appear to affect firms' carbon intensity or emissions levels. For example, although the estimated effects of the trade shock on these outcomes are positive, they do not reach statistical significance at conventional levels (Columns 3–4 of Panel A).

Export demand shocks do not influence total energy intensity but do increase energy expenditure (Column 6, $\beta = 0.406, \mathrm{p} < 0.010$). The next four columns present results from the same specification, disaggregating the energy intensity and energy cost variables into electricity and fuel components. Column 8 of Panel A shows a positive and statistically significant effect of the trade shock on electricity use ($\beta = 0.600, \mathrm{p} < 0.050$). When using fuel costs as the dependent variable, Column 10 shows that the coefficient on the trade shock is negative but not statistically significant. Based on these findings, we conclude that the observed increase in energy expenditure is driven exclusively by higher electricity consumption, not by increased fuel consumption. Accordingly, while export demand shock is insignificantly related to both total energy intensity and electricity intensity, it reduces fuel intensity ($\beta = -0.478, \mathrm{p} < 0.100$: see Column 9 of Panel A).

To summarize our results, we find that the increase in sales volume induced by the export demand shock leads to higher energy consumption—specifically electricity use—among affected manufacturing firms. As we do not observe any statistically significant effects on total energy intensity or electricity intensity, this suggests that value added also increases proportionally in response to expanding global markets. Indeed, additional analysis indicates that the export demand shock increases not only firms' total exports but also positively correlated with their value added (Column 2). Note however, that although the point estimate is large, it is not statistically significant at the conventional level ($\beta = 0.420, \mathrm{p} = 0.109$).

We further assume that the regression estimates for the overall demand shock may conceal important heterogeneity depending on whether the export demand shock is positive or negative. To better understand these differences, we separate the effects of the shock by their sign as follows:

$$\Delta Y_{f,t} = \beta_1 \Delta D_{f,t} I^N_{f,t} + \beta_2 \Delta D_{f,t} I^P_{f,t} + i_{t_0} + \Upsilon_t + \delta' X_{f,t_0} \times \Upsilon_t + \varepsilon_{f,t} \quad (4)$$

where $I^N_{f,t}$ is an indicator variable that equals 1 if the export demand shock experienced by firm f between year t_0 and t is negative and 0 otherwise. Similarly, $I^P_{f,t}$ is an indicator variable that equals 1 if the export demand shock for firm f is positive and 0 otherwise. The regression results for the negative and positive export demand shocks are reported in Panel B of Table 2. The findings show that a positive export demand shock increases total exports, while the effect of a negative export demand shock is statistically insignificant (Column 1 of Panel B). We also observe that both total energy costs and electricity costs rise during a positive phase but do not decrease in response to a negative shock (Columns 6 and 8 of Panel A). Although we do not find any significant relationship between total export demand shocks and electricity intensity overall, the disaggregated results reveal a positive correlation between electricity intensity and negative export demand shocks (Column 7 of Panel A). The positive coefficient in this case suggests that electricity intensity is reduced by firms affected by a more severe negative shock.

[Add Table 2 in here]

4.2 Heterogeneity analysis

Table 3 examines the differential effects of export demand shocks between firm-level characteristics, based on either firm's initial financial strength, greenness of top management and professional staff, or by dirtiness based on pollution intensity (Equation 3). The results using the stacked first differences model, with effects differentiated by firms' financial strength, are presented in Panel A of Table 3. The results show that export demand shocks are positively associated with export values, regardless of financial strength (Column 1 of Panel A). While the baseline results indicated no significant impact of export demand shocks on carbon intensity or emissions levels, Panel A reveals statistically significant positive effects for financially weaker firms. Specifically, Column 3 shows that export demand shocks increase carbon intensity in these firms ($\beta = 0.683, \mathrm{p} < 0.050$), an effect not observed in financially stronger firms. Column 4 further shows that this rise in carbon intensity is driven by an increase in emissions levels ($\beta = 0.772, \mathrm{p} < 0.050$) among financially weaker firms. In addition, we find that total energy costs and electricity costs increase in response to trade shocks for financially weaker firms, but not for their financially stronger counterparts (Columns 6 and 8 of Panel C). These results suggest that financial constraints may limit the ability of firms to adopt cleaner technologies, even when benefiting from expanded access to global markets.

Panel B reports the disaggregated results for green and non-green firms, based on the environmental consciousness of top management and professional staff. We find that export demand shocks increase export values regardless of a firm's environmental orientation (Column 1 of Panel B). Similarly, we find that an increase in export demand leads to higher total energy consumption—particularly electricity use—both in non-green and green firms (Columns 6 and 8 of Panel B). However, the overall effect masks some important heterogeneity in the relationship between trade shocks and firm-level environmental performance. Specifically, an increase in export demand leads to a reduction in carbon intensity in firms with environmentally conscious top management or professional staff; in these firms, the estimated coefficient is negative and statistically significant (Column 2: $\beta = -0.449, \mathrm{p} < 0.050$). Interestingly however, reverse is true for energy intensity of fuels, which yields a negative and statistically significant estimate in less green firms but not in more green firms (Column 9 of Panel B).

Panel C of Table 3 reports the heterogeneity analysis based on initial pollution intensity of the industry where the firm is operating. The results demonstrate that export demand shocks increase energy and electricity costs solely among firms operating in clean industries (Columns 6 and 8 of Panel C). There is also some evidence to show that especially dirtier firms benefit more from trade shocks by lowering their fuel intensity, a result that is in line with previous studies (Feng and Wei, 2023; Lehr, 2025; Wang et al., 2024).

[Add Table 3 in here]

5 Robustness tests

The results on the effect of export demand shocks on environmental performance are subjected to several robustness and sensitivity checks, including the use of alternative measures, estimation samples, and model specifications. First, we use alternative definitions of carbon and energy intensity, calculated as emissions and energy expenditure relative to sales. The results, presented in Table A1 of the Appendix (Panel A), are broadly consistent with our main findings. The only exception is that the correlation between the export demand shock and fuel intensity is no longer statistically significant. Second, we apply an alternative clustering of standard errors at the firm level. As shown in Panel B of Table A1, the results remain robust to this change.

Third, following Lehr (2025), we exclude the economic sectors classified under "manufacture of electrical and optical equipment." These sectors—such as the manufacturing of office machines and communication equipment—have undergone rapid technological changes and declining prices, which may distort comparisons of deflated sales and value added over time. As reported in Panel C of Table A1, the results remain largely unchanged for total energy and electricity expenditure, while the coefficient for fuel intensity becomes statistically insignificant ($\beta = –0.463, \text{p} = 0.124$).

Fourth, one potential concern with the analysis is that the statistically insignificant results regarding carbon and energy intensity may be driven by firms that exited exporting. Note that our estimation sample includes firms that were exporters in the initial year (t_0), but not necessarily in the final year (t), conditional on firm survival. Firms that stop exporting are likely to experience a decline in value added due to lower margins, reduced investments, and smaller scale. In contrast, energy use may remain stable or decline only modestly, partly due to fixed operational energy needs and depending on how well firms adjust to serving the domestic market. Under this scenario, energy intensity would rise among firms that exit exporting. This would be consistent with previous studies showing that non-exporting firms tend to exhibit higher emissions intensity compared to exporters (e.g., Jinji and Sakamoto, 2015; Cui et al., 2016; Holladay, 2016; Forslid et al., 2018). To address this concern, we re-estimate the effect of the export demand shock on a subsample of incumbent exporters—firms that continue exporting throughout the sample period. The results, presented in Panel D of Table A1, do not support the hypothesis that the observed environmental effects are driven by firms exiting export markets.

Fifth, we determine the firm's initial financial strength based on its liquidity, which is another common proxy of a firm's credit constraint. While equity ratio reflects how reliant the firm is on its own capital versus external debt, liquidity ratio assesses a company's ability to meet short-term obligations. Given this, initial financial strength is measured by the quick ratio in the base year (t_0). The regression estimates on export demand shocks are given in Panel A of Table A2. Based on the findings, we no longer find statistically significant correlation coefficients for carbon intensity or emission levels in financially weaker firms. The export demand shock on total energy and electricity costs also yield a positive effect, regardless on the firm's initial liquidity (Columns 5 and 7 of Panel A). To summarize the findings, financially weaker firms tend to respond more strongly to export demand shocks when such financial strength is measured using the equity ratio, and less so when using the quick ratio. This difference likely arises from the nature of the shock: responding to export opportunities often requires strategic, forward-looking decisions—such as expanding production capacity or investing in new technology—that depend on the firm's ability to take on financial risk and invest over the medium to long term. Firms with higher equity ratios are better positioned to make such investments, for example, by leveraging their stronger capital structure to access external financing. In contrast, the quick ratio is more indicative of short-term operational liquidity, which may not directly constrain or enable the types of investment decisions associated with export demand shocks.

Finally, we consider an alternative measure of firm greenness. While occupation-specific approach categorizes workers based on their work tasks, it does not explicitly capture the specific human capital skills of workers in environmental fields. To do so, a firm's environmental orientation is measured by including interaction terms in Equation (3), where we define $I_(f, t_0)^L$ to equal 1 if no individual in the firm's top management or professional staff has expertise in environmental issues, as determined by their field of study, and 0 otherwise. Conversely, $I_(f, t_0)^H$ equals 1 if at least one member of top management or professional staff holds a degree in an environmental field, and 0 otherwise. [10]

The results are reported in Panel B of Table A2. The results suggest that both total energy and electricity costs increase in response to an export demand shock, particularly in less green firms (Columns 5 and 7 of Panel B). Our interpretation is that firms employing key staff with educational backgrounds in environmental fields are more likely to exhibit lower energy consumption, as these employees contribute specialized knowledge, may promote the adoption of clean technologies, and foster values that support resource expenditure cuts. However, the statistically insignificant coefficients for greener firms may be due to smaller sample sizes, not due to lower point estimates. [11] Additionally, the results do not remain robust to carbon intensity, for which we no longer find a decreasing trend in firms that are considered as greener based on environmental orientation of managerial and professional staff (Column 1 of Panel B).

[10] Based on 6-digit ISCED education classification, 42 were classified as degrees (mostly higher-level) in environmental fields.

[11] We note that the number of firms with environmental expertise in their top management or professional staff, based on education, is generally quite low (approximately 5% of firms).

5.1 Potential mechanisms

We propose that innovations could be a potential mechanism linking export demand shocks to a firm's environmental performance (Alam et al., 2019; Bagchi et al., 2022; Jung et al., 2021; Lee and Min, 2015). The relationships between export demand shocks and innovation-related activities are presented in Table 4 (Panel A, Columns 1-5). The results show that firms that are being exposed to a higher export demand allocate more resources to internal R&D, the effect being statistically significant at the 10% significance level ($\beta = 1.243, \mathrm{p} < 0.100$). However, the results do not reveal any statistically significant associations between export demand shocks and other firm-level innovation or investment activities. As firm's financial position is correlated with innovation and technology adaption enhancement activity, we consider heterogeneity in the results by a firm's initial equity at initial year. The results in Panel B suggest that financially stronger firms respond to expanding export markets by investing more on new machinery and by increasing internal R&D (Columns 2 and 5).

The next two columns present the results using proxy variables for product mix as outcome variables. Changing trade environment often lead firms to adjust their product portfolio, shifting toward their best-performing and cleaner products (Barrows and Ollivier, 2021). If firms adjust to export demand by dropping their marginal products – that typically exhibit higher energy intensity – this would ultimately lead to reduced energy intensity. However, the results do not indicate that export demand would affect the number of exported products of affected firms (Column 6). Instead, single-product firms seem to diversify into multi-product operations when global market demand expands ($\beta = -0.062, \mathrm{p} < 0.100$; Column 7 of Panel A).

[Add Table 4 in here]

6 Conclusions

This study examined how export demand shocks impact the environmental performance of Finnish manufacturing firms. Using unique administrative data from 1999-2019, we constructed firm-level measures of export demand shocks and analyze their effects on various environmental indicators. Our key findings indicate that the overall effect of export shocks on improving environmental performance is limited, with no significant impacts on the carbon intensity or total energy intensity of affected firms. Previous studies mostly document that foreign demand shocks lead to reduction in emissions intensity (Barrows and Ollivier, 2021; Wang et al., 2024; Xie and Li, 2024). When we disaggregate total energy intensity into electricity and fuel components (relative to value added), we find that fuel intensity declines in response to a trade shock, a result that remains robust across most sensitivity checks. In contrast, the increase in sales volume induced by an export demand shock leads to higher overall energy consumption, driven specifically by greater electricity use but not by fuel use, among affected manufacturing firms. Taken together, these results suggest that expanding international trade may harm the domestic environment.

However, there is some indication that trade shocks may encourage firms to shift from fuel-powered equipment toward (likely cleaner) electricity-powered alternatives. Notably, the reduction in fuel intensity occurs only among firms operating in dirty industries. This finding is consistent with earlier evidence showing that firms with larger initial pollution base also exhibit larger marginal effects on energy savings (Feng and Wei, 2023; Lehr, 2025; Wang et al., 2024). Compared with cleaner firms, dirty firms also tend to have higher energy costs and are therefore more motivated to restrain energy use to increased sales and production. This pattern is evident in Finnish manufacturing: in response to trade shock, energy and electricity costs rise for clean firms but not for dirty firms.

Additional analyses reveal important heterogeneities in the results when considering firm characteristics based on firm's financial strength, offering important contributions to the existing literature. Financially weaker firms – when measured to describe long-term solvency and resilience – experience increases in carbon intensity, as well as rises in both emissions and energy costs, when faced with export demand shocks. This pattern suggests that financial constraints may hinder firms' ability to invest in cleaner technologies or practices during periods of production expansions. In contrast, we find no consistent effects on environmental performance among financially stronger firms, indicating that a stronger financial position may help mitigate the negative environmental impacts of trade shocks.

The mechanisms linking trade shocks to environmental performance are less straightforward. Our baseline results indicate that firms exposed to export demand shocks generally reduce fuel intensity, a change explained primarily by the increase in value added (scale effect) rather than by changes in fuel costs. We do not find conclusive evidence that this pattern is driven by innovation or technical improvements. However, the absence of direct measures on environmental investments or technological upgrading may limit the strength of our conclusion. Future research could explore alternative mechanisms behind the reduction in fuel intensity, such as energy aid programs, green patenting, or shifts toward greener products, could further elucidate these dynamics. Our results also do not support a product-mix explanation. Specifically, Finnish manufacturing firms do not appear to respond to export demand shocks by dropping marginal products and shifting toward their best-performing - and potentially cleaner - products. Instead, single-product firms tend to diversify into multi-product operations when global market demand expands.

Our results have important implications for understanding the complex relationship between trade and environmental outcomes at the firm level. They highlight that the environmental impacts of trade shocks are not uniform across firms, but rather depend on firms' existing pollution intensity and financial strength. Our findings suggest that policies aiming to promote both export growth and environmental sustainability should consider these firm-level heterogeneities. Addressing financial constraints may be crucial for ensuring that export growth translates into improved environmental performance. Future research could further explore the mechanisms behind these heterogeneous effects, such as differences in management practices. Additionally, examining longer-term impacts and potential spillover effects across firms and industries could provide valuable insights for policy design.

References

Aghion, P., Askenazy, P., Berman, N., Cette, G., and Eymard, L. (2012). Credit constraints and the cyclicality of R&D investment: Evidence from France. *Journal of the European Economic Association*, 10(5):1001–1024.

Aghion, P., Bergeaud, A., Lequien, M., and Melitz, M. J. (2024). The heterogeneous impact of market size on innovation: Evidence from French firm-level exports. *Review of Economics and Statistics*, 106(3):608–626.

Alam, M. S., Atif, M., Chien-Chi, C., and Soytaş, U. (2019). Does corporate R&D investment affect firm environmental performance? Evidence from G-6 countries. *Energy Economics*, 78:401–411.

Autor, D. H., Dorn, D., and Hanson, G. H. (2013). The China syndrome: Local labor market effects of import competition in the United States. *American Economic Review*, 103(6):2121–2168.

Bagchi, P., Sahu, S. K., Kumar, A., and Tan, K. H. (2022). Analysis of carbon productivity for firms in the manufacturing sector of India. *Technological Forecasting and Social Change*, 178:121606.

Barlevy, G. (2007). On the cyclicality of research and development. *American Economic Review*, 97(4):1131–1164.

Barrows, G. and Ollivier, H. (2021). Foreign demand, developing country exports, and CO_2 emissions: Firm-level evidence from India. *Journal of Development Economics*, 149:102587.

Bartik, T. J. (1991). Who benefits from state and local economic development policies?

Batrakova, S. and Davies, R. B. (2012). Is there an environmental benefit to being an exporter? Evidence from firm-level data. *Review of World Economics*, 148:449–474.

Borusyak, K., Hull, P., and Jaravel, X. (2022). Quasi-experimental shift-share research designs. *The Review of economic studies*, 89(1):181–213.

Cherniwchan, J. (2017). Trade liberalization and the environment: Evidence from NAFTA and US manufacturing. *Journal of International Economics*, 105:130–149.

Cohn, J. and Deryugina, T. (2018). Firm-level financial resources and environmental spills. National Bureau of Economic Research.

Cui, J., Lapan, H., and Moschini, G. (2016). Productivity, export, and environmental performance: Air pollutants in the United States. *American Journal of Agricultural Economics*, 98(2):447–467.

Feng, Q. and Wei, H. (2023). Import competition and firm energy intensity: Evidence from China. *Economic Analysis and Policy*, 78:543–560.

Forslid, R., Okubo, T., and Ulltveit-Moe, K. H. (2018). Why are firms that export cleaner? International trade, abatement and environmental emissions. *Journal of Environmental Economics and Management*, 91:166–183.

Galdeano-Gómez, E. (2010). Exporting and environmental performance: A firm-level productivity analysis. *World Economy*, 33(1):60–88.

Girma, S., Hanley, A., and Tintelnot, F. (2008). Exporting and the environment: A new look with micro-data. Kiel Working Paper.

Goetz, M. (2019). Financing conditions and toxic emissions. SAFE working paper.

Goldar, B. and Goldar, A. (2023). Impact of export intensity on energy intensity in manufacturing plants: Evidence from India. *The Journal of International Trade & Economic Development*, 32(4):639–664.

Goldsmith-Pinkham, P., Sorkin, I., and Swift, H. (2020). Bartik instruments: What, when, why, and how. *American Economic Review*, 110(8):2586–2624.

Gutiérrez, E. and Teshima, K. (2018). Abatement expenditures, technology choice, and environmental performance: Evidence from firm responses to import competition in Mexico. *Journal of Development Economics*, 133:264–274.

Hanley, A. and Semrau, F. O. (2022). Stepping up to the mark? Firms' export activity and environmental innovation in 14 European countries. *Industry and Innovation*, 29(5):672–700.

Holladay, J. S. (2016). Exporters and the environment. *Canadian Journal of Economics/Revue canadienne d'économique*, 49(1):147–172.

Hong, H., Kubik, J. D., and Scheinkman, J. A. (2012). Financial constraints on corporate goodness. National Bureau of Economic Research.

Hummels, D., Jørgensen, R., Munch, J., and Xiang, C. (2014). The wage effects of offshoring: Evidence from Danish matched worker-firm data. *American Economic Review*, 104(6):1597–1629.

Jinji, N. and Sakamoto, H. (2015). Does exporting improve firms' CO_2 emissions intensity and energy intensity? Evidence from Japanese manufacturing. *Research Institute for Economy, Trade and Industry Discussion Paper*.

Jung, H., Song, S., Ahn, Y.-H., Hwang, H., and Song, C.-K. (2021). Effects of emission trading schemes on corporate carbon productivity and implications for firm-level responses. *Scientific reports*, 11(1):11679.

Knudsen, A. and Lopatin, N. (2023). Credit constraints and spillover effects of financial market liberalization: Case of Colombia. *The Quarterly Review of Economics and Finance*, 87:132–141.

Lee, K.-H. and Min, B. (2015). Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *Journal of cleaner production*, 108:534–542.

Lehr, J. (2025). Import competition and firm-level CO_2 emissions: Evidence from the German manufacturing industry. *Canadian Journal of Economics/Revue canadienne d'économique*, 58(2):747–770.

Levine, R., Lin, C., Wang, Z., and Xie, W. (2018). Bank liquidity, credit supply, and the environment. National Bureau of Economic Research.

Maczulskij, T. (2024). How are green jobs created? A decomposition analysis. *Economics Letters*, 244:111950.

Mahapatra, S. K., Schoenherr, T., and Jayaram, J. (2021). An assessment of factors contributing to firms' carbon footprint reduction efforts. *International Journal of Production Economics*, 235:108073.

Ouyang, M. (2011). On the cyclicality of R&D. *Review of Economics and Statistics*, 93(2):542–553.

Roy, J. and Yasar, M. (2015). Energy efficiency and exporting: Evidence from firm-level data. *Energy Economics*, 52:127–135.

Scholl, N., Turban, S., and Gal, P. N. (2023). The green side of productivity: An international classification of green and brown occupations. OECD Publishing.

Tran, T. M. (2022). Environmental benefit gain from exporting: Evidence from Vietnam. *The World Economy*, 45(4):1081–1111.

Wagner, J. (2014). Credit constraints and exports: A survey of empirical studies using firm-level data. *Industrial and Corporate Change*, 23(6):1477–1492.

Wang, S., Ma, X., Zhang, X., and Kang, M. (2024). Can foreign demand shocks reduce the pollution emission intensity? Evidence from exporters in China. *Energy Economics*, 133:107515.

Wang, Z. (2021). Blame the foreigners? Exports and sulfur dioxide emissions in China. *Environmental and Resource Economics*, 80(2):279–309.

Xie, H. and Li, C. (2024). Foreign demand shocks and CO_2 emission intensity: Firm-level evidence from China. *Applied Economics Letters*, pages 1–5.

Xu, Q. and Kim, T. (2022). Financial constraints and corporate environmental policies. *The Review of Financial Studies*, 35(2):576–635.

Tables

Table 1: Summary statistics of variables

	Period 1		Period 2	
	1999	2007	2008	2018
GHG emissions (M t CO2 eq.)	0.094	0.095	0.096	0.057
Energy expenditure (in millions €)	0.183	0.293	0.290	0.235
Carbon intensity	0.0008	0.0007	0.0013	0.0016
Energy intensity	0.036	0.047	0.050	0.118
Total value of exports (in millions €)	14.64	20.16	32.13	23.34
Sales (in millions €)	33.67	46.97	93.93	56.17
Value added (in millions €)	10.61	12.51	19.01	13.99
Number of employees	144.04	136.30	187.61	147.20
Equity ratio	42.63	43.58	43.23	45.99
Exporter	1.00	0.88	1.00	0.83
Food products and beverages	0.057	0.058	0.064	0.063
Textiles, wearing and leather products	0.058	0.055	0.042	0.042
Wood, pulp and paper products	0.191	0.191	0.129	0.130
Chemicals, rubber and non-metallic products	0.161	0.162	0.193	0.191
Metal products	0.142	0.148	0.173	0.171
Machinery and equipment	0.160	0.164	0.191	0.195
Electrical and optical equipment	0.090	0.085	0.099	0.099
Transport equipment	0.060	0.056	0.057	0.057
Furniture and recycling	0.081	0.081	0.053	0.051
Number of firms	923	923	881	881
Number of firms, emissions data	120	120	117	117

Notes: The samples for both initial years (1999 and 2008) include manufacturing exporters with at least 20 employees in a firm. We focus on firms that were observed both in initial and end year.

Table 2: The effect of export demand shock on exports, value added and firm's environmental performance, 1999–2018

	Exports	Value added	Carbon intensity	GHG emissions	Energy intensity	Energy expenditure	Energy intensity, electricity	Energy expenditure, electricity	Energy intensity, fuels	Energy expenditure, fuels
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Effect of export demand shock										
Export shock	2.439***	0.420	0.242	0.365	-0.014	0.406***	0.168	0.600**	-0.478*	-0.165
	(0.5310)	(0.2328)	(0.2356)	(0.4273)	(0.2224)	(0.0978)	(0.3044)	(0.1898)	(0.2396)	(0.2610)
Obs.	1,804	1,804	237	237	1,804	1,804	1,762	1,762	1,230	1,230
R^2	0.048	0.066	0.080	0.048	0.054	0.089	0.064	0.094	0.058	0.101
Panel B: Effects of negative and positive export demand shocks										
Negative shock	-1.056	0.539	-0.078	0.982	0.168	0.707	1.331*	1.871	-0.845	-0.579
	(0.9650)	(0.6812)	(0.8154)	(1.492)	(0.5161)	(0.8514)	(0.6759)	(1.209)	(0.7125)	(1.0413)
Positive shock	2.829***	0.407	0.388	0.082	-0.035	0.372***	0.034	0.443**	-0.428	-0.109
	(0.5871)	(0.2379)	(0.4208)	(0.5343)	(0.2295)	(0.0964)	(0.2924)	(0.1567)	(0.2682)	(0.2886)
Obs.	1,804	1,804	237	237	1,804	1,804	1,762	1,762	1,230	1,230
R^2	0.051	0.066	0.081	0.050	0.054	0.089	0.065	0.095	0.058	0.101

Notes: Carbon intensity is measured as firm's annual emissions over value added. Energy intensities are measured as energy expenditure over value added. Models are estimated using stacked first difference estimation, using two sub-periods. Each outcome is expressed in logarithms. Other controls include industry, time period fixed effects and interactions between initial firm size (number of employees) and sales with year indicator. Standard errors (in parentheses) are clustered at industry level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3: Heterogeneity analysis: the effect of export demand shock on exports, value added and firm's environmental performance, 1999-2018

	Exports	Value added	Carbon intensity	GHG emissions	Energy intensity	Energy expenditure	Energy intensity, electricity	Energy expenditure, electricity	Energy intensity, fuels	Energy expenditure, fuels
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Effect of export demand shock by a firm's financial strength										
Shock × Fin_low	2.528***	0.479*	0.683**	0.772**	0.028	0.507***	0.327	0.801***	-0.521	-0.213
	(0.6586)	(0.2090)	(0.2244)	(0.2565)	(0.3029)	(0.1461)	(0.3346)	(0.2092)	(0.3758)	(0.2602)
Shock × Fin_high	2.364***	0.371	-0.367	-0.195	-0.049	0.321	0.035	0.430	-0.447	-0.130
	(0.6687)	(0.2628)	(0.3234)	(0.5338)	(0.2124)	(0.1762)	(0.2997)	(0.2376)	(0.2993)	(0.3694)
Obs.	1,804	1,804	237	237	1,804	1,804	1,762	1,762	1,230	1,230
R^2	0.048	0.066	0.086	0.054	0.054	0.089	0.065	0.094	0.058	0.101
Panel B: Effect of export demand shock by a firm's greenness										
Shock × Nongreen	2.366***	0.440*	0.374	0.461	-0.028	0.412***	0.167	0.608**	-0.504*	-0.189
	(0.5266)	(0.2280)	(0.2656)	(0.4240)	(0.2358)	(0.1018)	(0.3477)	(0.2216)	(0.2660)	(0.3232)
Shock × Green	2.581***	0.380	-0.449**	-0.135	0.013	0.393**	0.172	0.583***	0.430	-0.122
	(0.7401)	(0.2607)	(0.1934)	(0.3827)	(0.2549)	(0.1642)	(0.2961)	(0.1706)	(0.4384)	(0.4454)
Obs.	1,804	1,804	237	237	1,804	1,804	1,762	1,762	1,230	1,230
R^2	0.048	0.066	0.083	0.050	0.054	0.089	0.064	0.094	0.058	0.101
Panel C: Effect of export demand shock by firm dirtiness										
Shock × Dirty	2.610***	0.426	0.248	0.130	-0.315	0.111	-0.224	0.235	-0.387***	-0.108
	(0.6989)	(0.2886)	(0.3446)	(0.3067)	(0.5338)	(0.3012)	(0.6666)	(0.4086)	(0.1040)	(0.2051)
Shock × Clean	2.369**	0.418	0.236	0.577	0.108	0.525*	0.329	0.749***	-0.513	-0.187
	(0.6035)	(0.2400)	(0.4234)	(0.6077)	(0.1884)	(0.1786)	(0.2043)	(0.2052)	(0.3272)	(0.3332)
Obs.	1,804	1,804	237	237	1,804	1,804	1,762	1,762	1,230	1,230
R^2	0.048	0.066	0.080	0.083	0.054	0.089	0.065	0.094	0.058	0.101

Notes: Carbon intensity is measured as firm's annual emissions over value added. Energy intensities are measured as energy expenditure over value added. Models are estimated using stacked first difference estimation, using two sub-periods. Each outcome is expressed in logarithms. Financially low (high) indicates that the equity ratio is below (above) the median equity ratio within the 2-digit sector where the firm operates. Non-green (green) indicates that the share of environmentally conscious top management and professional staff is below (above) the median share within the 2-digit sector. Dirty (clean) firms are classified as those firms operating in sectors that fall below (above) the pollution intensity within the 2-digit sector. Other controls include industry, time period fixed effects and interactions between initial firm size (number of employees) and sales with year indicators. Standard errors (in parentheses) are clustered at industry level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: The effect of export demand shock on firm's innovation activity and product-mix outcomes, 1999–2018

	Process innovation (1)	Additions in machinery (2)	Revenue from patents (3)	STEM workers (4)	Internal R&D (5)	Number of products (6)	Single-product firm (7)
Panel A: The effect of export demand shock							
Export shock	-0.059	0.767	0.760	0.083	1.243*	0.006	-0.062*
	(0.1012)	(0.5289)	(0.4818)	(0.1151)	(0.6161)	(0.0935)	(0.0306)
Obs.	397	1,742	1,804	1,796	684	1,627	1,627
R^2	0.053	0.033	0.051	0.033	0.014	0.038	0.014
Panel B: Effect of export demand shock by a firm's financial strength							
Shock × Fin_low	0.040	0.424	0.818	-0.020	1.223	-0.060	-0.075
	(0.1223)	(0.7251)	(0.5238)	(0.1342)	(0.8335)	(0.1123)	(0.0548)
Shock × Fin_high	-0.116	1.047**	0.558	0.170	1.258*	-0.063	-0.050*
	(0.1523)	(0.3934)	(0.5408)	(0.1048)	(0.5983)	(0.1096)	(0.0251)
Obs.	397	1,742	1,804	1,796	684	1,627	1,627
R^2	0.053	0.034	0.052	0.035	0.014	0.039	0.014

Notes: Models are estimated using stacked first difference estimation, using two sub-periods. Process innovation and single-product firm are indicator variables, whereas others are expressed in logarithms. Financially low (high) indicates that the equity ratio is below (above) the median equity ratio within the 2-digit sector where the firm operates. Other controls include industry, time period fixed effects and interactions between initial firm size (number of employees) and sales with year indicator. Standard errors (in parentheses) are clustered at industry level.. *** $p < 0.01$, ** $p < 0.05$, $*p < 0.1$.

Appendix

Table A1: The effect of export demand shock on firm's environmental performance, 1999–2018

	Carbon intensity	GHG emissions	Energy intensity	Energy expenditure	Energy intensity, electricity	Energy expenditure, electricity	Energy intensity, fuels	Energy expenditure, fuels
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Carbon and energy intensity measured over sales								
Export shock	0.352		0.095		0.272		-0.329	
	(0.3659)		(0.1412)		(0.2248)		(0.2680)	
Obs.	237		1,804		1,762		1,230	
R^2	0.049		0.045		0.053		0.057	
Panel B: Firm-level clustered standard errors								
Export shock	0.242	0.365	-0.014	0.406**	0.168	0.600***	-0.478**	-0.165
	(0.4944)	(0.5298)	(0.1644)	(0.1583)	(0.1908)	(0.1944)	(0.2315)	(0.2316)
Obs.	237	237	1,804	1,804	1,762	1,762	1,230	1,230
R^2	0.080	0.048	0.054	0.089	0.064	0.094	0.058	0.101
Panel C: Excluding sectors 30–33 (electrical and optical equipment)								
Export shock	0.242	0.365	0.149	0.394***	0.389	0.636**	-0.463	-0.290
	(0.2369)	(0.4298)	(0.1780)	(0.1076)	(0.2233)	(0.2075)	(0.2646)	(0.2589)
Obs.	236	236	1,634	1,634	1,596	1,595	1,143	1,143
R^2	0.080	0.048	0.052	0.092	0.063	0.096	0.042	0.085
Panel D: Including incumbent exporters only								
Export shock	-0.248	-0.178	-0.027	0.373***	0.185	0.596***	-0.573**	-0.298
	(0.3842)	(0.3489)	(0.1918)	(0.0830)	(0.2804)	(0.1683)	(0.2176)	(0.2725)
Obs.	188	188	1,627	1,627	1,589	1,589	1,093	1,093
R^2	0.065	0.064	0.064	0.107	0.069	0.101	0.061	0.101

Notes: Carbon intensity is measured as firm's annual emissions over value added (Panels B–D) or over sales (Panel A). Energy intensities are measured as energy expenditure over value added (Panels B–D) or over sales (Panel A). Models are estimated using stacked first difference estimation, using two sub-periods. Each outcome is expressed in logarithms. Other controls include industry, time period fixed effects and interactions between initial firm size (number of employees) and sales with year indicators. Standard errors (in parentheses) are clustered at industry level (Panels A, C–D) or at firm-level (Panel B). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2: The effect of export demand shock on firm's environmental performance, 1999–2018

	Carbon intensity	GHG emissions	Energy intensity	Energy expenditure	Energy intensity, electricity	Energy expenditure, electricity	Energy intensity, fuels	Energy expenditure, fuels
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Effect of export demand shock by a firm's financial strength								
Shock x Fin_low	0.273	0.051	-0.080	0.405**	0.188	0.674***	-0.504*	-0.164
	(0.6434)	(0.5743)	(0.2430)	(0.1481)	(0.2848)	(0.1849)	(0.2604)	(0.2500)
Shock x Fin_high	0.290	0.608	0.019	0.405**	0.143	0.548*	-0.463	-0.168
	(0.4298)	(0.6049)	(0.2688)	(0.1604)	(0.3694)	(0.2610)	(0.3106)	(0.3453)
Obs.	233	233	1,791	1,791	1,750	1,750	1,222	1,222
R^2	0.093	0.052	0.055	0.090	0.066	0.096	0.059	0.102
Panel B: Effect of export demand shock by a firm's greenness								
Shock x Nongreen	0.163	0.363	0.025	0.423***	0.182	0.588**	-0.431	-0.130
	(0.3108)	(0.7192)	(0.2125)	(0.1173)	(0.2817)	(0.1934)	(0.2571)	(0.2923)
Shock x Green	0.437	0.372	-0.440	0.222	0.023	0.718	-1.150	-0.656
	(0.6414)	(0.6230)	(0.6951)	(0.6151)	(0.8369)	(0.7603)	(1.095)	(0.9498)
Obs.	237	237	1,804	1,804	1,762	1,762	1,230	1,230
R^2	0.080	0.048	0.054	0.089	0.064	0.094	0.058	0.101

Notes: Carbon intensity is measured as firm's annual emissions over value added (Panels B–D) or over sales (Panel A). Energy intensities are measured as energy expenditure over value added (Panels B–D) or over sales (Panel A). Models are estimated using stacked first difference estimation, using two sub-periods. Each outcome is expressed in logarithms. Other controls include industry, time period fixed effects and interactions between initial firm size (number of employees) and sales with year indicators. Standard errors (in parentheses) are clustered at industry level (Panels A, C–D) or at firm-level (Panel B). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

ETLA

Elinkeinoelämän tutkimuslaitos

ETLA Economic Research

ISSN-L 2323-2420
ISSN 2323-2420 (print)
ISSN 2323-2439 (pdf)

Publisher: Taloustieto Oy

Tel. +358-9-609 900
www.etla.fi
firstname.lastname@etla.fi

Arkadiankatu 23 B
FIN-00100 Helsinki