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Carbon Footprints in a Global Marketplace

Firm-Level Insights on Trade and the Environment

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Firm-Level Insights on Trade and the Environment

by Albert Duodu

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DOCTORAL DISSERTATION
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Carbon Footprints in a Global Marketplace: Firm-Level Insights on Trade and the Environment

Abstract
This doctoral thesis consists of three independent research papers. All papers are empirical and cover the area of international trade and environmental economics, with particular focus on Swedish manufacturing firms.

The first paper investigates how carbon offshoring could contribute to cleaner production. Using Swedish firm-product level data from 2005-2014, combined with instrumental variable and dynamic difference-in-difference estimation techniques, the study finds that increased imports of emission-intensive goods makes firms' production processes cleaner by 5%, but also raises transport emissions by 2%. It also highlights that offshoring through foreign direct investment (FDI) could potentially have a larger impact on reducing emissions compared to importing inputs not produced in-house.

The second paper explores how import competition influences the environmental behavior of local firms in Sweden. Using detailed geographical information about the location of all manufacturing firms in Sweden, the study finds that firms facing import competition tend to become more emission efficient, with the effect diminishing as the distance between the producer and the importer increases. This emissions reduction is attributed to productivity spillovers, shifts in product mix, and investments in emissions abatement.

The third paper, examines the impact of energy prices on manufacturing firms by using a shift-share instrument and a dynamic difference-in-difference approaches that isolate the exogenous variation in firm-level energy prices. I find that higher energy prices, driven by increased carbon pricing, both benefit the environment by reducing emissions and have potentially harmful economics effects by lowering productivity and employment, particularly for highly skilled workers. Firms are more likely to pass on costs to consumers, worsening inflation, and the most affected are those with high energy intensity and those outside the EU Emissions Trading System (EU-ETS).

Key words
Offshoring, Swedish Firms, Emissions, Import Competition, Energy Price, Productivity, Employment, Carbon leakage, Pass-through

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Dedicated to my Mum
Mercy Ayisah

Contents

Abstract

This thesis adds to the body of research in international trade, environmental, and energy economics. It comprises of three distinct yet interconnected papers, each addressing a different facet of the green manufacturing transition within the context of global trade, and environmental policies.

The first paper, *Carbon offshoring and manufacturing-cleanup*, investigates the causal evidence of how carbon offshoring could contribute to lower emission intensity of manufacturing firms. Production in manufacturing firms in high income countries is generally becoming cleaner. Some of this trend has been shown to be due to the adoption of new technologies, but carbon offshoring – i.e. when dirty production at home is replaced with imports of carbon-intensive products from abroad – may be an additional factor. If so, this is concerning, because it risks undermining climate policies by simply moving emissions to countries with laxer regulations. This is the focus of this paper. Leveraging rich Swedish firm-product level data between 2006-2014, and employing a combination of shift-share instrumental variables and a difference-in-difference estimation approach, I find a compelling paradox: A 10% increase in the import of emission-intensive goods can result in firms' production processes becoming 5% cleaner but increases transport emissions by 2%. This suggests that carbon offshoring does not only shift emissions elsewhere but also generates new ones (via transportation). Additionally, I show that the type of offshoring matters. For instance, foreign direct investment (FDI) has a much larger emissions-reducing effect than offshoring in the form of imports of inputs not produced in-firm.

The second paper, *Local import competition and firm-level emissions* (joint with Zouheir El-Sahli), examines the effect of spatially localized import competition shocks on the environmental performance of local upstream producers. It is established in the literature that import competition may lead to efficiency gains in the firms facing such competition. It is, however, unclear whether such gains extend to the firms' environmental behavior. We contribute to the literature by investigating how local import competition, defined at different spatial dimensions within Sweden, may affect emissions by the local producing firms. Using detailed geographical information about the location of all manufacturing firms in Sweden, we find no evidence that import competition matters at the national level, but local import competition reduces

firm-level emissions. This effect wanes with the distance between the producer and the importer. The emissions reduction is driven by productivity spillovers, changes in the product mix, and emissions abatement investment.

The third paper, *Environment and the Economy: firm-level responses to energy price shocks*, discusses the trade-off between environmental and economic goals due energy price shocks. Although raising the carbon price is an effective tool for decreasing reliance on carbon-intensive production sources, it has also raised substantial concerns among policymakers that higher energy costs will render manufacturing firms less competitive and potentially lead to increased consumer prices. Using firm-level data from 2006-2014, I examined the impact of energy prices on manufacturing firms using a shift-share instrument and dynamic difference-in-difference approach that isolate the exogenous variation in firm-level energy prices. The analysis reveals a dual impact of energy price inflation. On the one hand, energy price shock contributes to positive environmental outcomes by reducing energy consumption and CO_2 emissions. On the other hand, it exerts detrimental effects on firms' productivity, employment, and the risk of potential carbon leakage. Furthermore, firms demonstrate a propensity to shift the cost burdens to consumers, exacerbating general inflation in the economy. Additional results show that the negative effect on employment affects highly skilled workers disproportionately: employment among workers with university degrees fell considerably in the short run, whereas employment for those with high school degrees increased. The most affected firms are high-energy intensive and non-EU-ETS firms. Overall, the findings suggest a trade-off between environmental and economic goals due to increasing energy taxes.

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The curriculum is so much necessary raw material, but warmth is the vital element for the growing plant and the soul of a child
— Carl Jung

First, I would love to express my profound honour and gratitude to the Almighty God, the giver of life. This work would not have been completed if not for his abundant mercies, grace, and favour.

Looking back, I feel infinitely lucky to have had the opportunity to study for a PhD, and incredibly blessed with good kind people who took huge bets on me, loved me and and made me feel special. I hope that the past five years have molded me into a better economist, a more confident researcher, and a resilient individual. This thesis stands as the pinnacle of that transformative journey, made achievable only through the support of a select group of extraordinary individuals.

I often emphasize to new students the importance of having advisors who genuinely care about them as people. In this dimension, I struck gold. I am overwhelmed with gratitude for my main advisor, Maria Persson. Maria has not only been my academic guide but also the beacon of light I needed in my journey. Her unwavering efforts to nurture my growth and bring out the best in me have touched my heart deeply. It's the little gestures of kindness she shows that make me feel truly seen and cared for as a person, beyond just my research pursuits. Maria's comments, instructions, and profound intelligence have been the cornerstone of this thesis. I owe her a debt of gratitude that words cannot fully express. To Joakim Gullstrand, my heartfelt thanks for being a constant source of inspiration and guidance since the start of my masters degree in Economics. You were the one who introduced me to the intricacies of Swedish micro-level trade data, and your support has been invaluable in navigating through its complexities. Your generosity as a teacher and friend will always be cherished. And to Fredrik NG Andersson, you have fundamentally altered the way I perceive economic concepts. Your boundless enthusiasm and innovative ideas reignite my passion for economics, especially during the toughest moments of my research journey. It's been an honor to learn from you and be supported by you. For inspiring me to aim high in my research, for remarkably insightful suggestions

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The completion of this thesis stands as a testament to the steadfast support of my family and friends. I dedicate this significant achievement to my greatest source of

inspiration, my mother, Mercy Ayisah, whose unwavering belief in me propelled me forward. A big thank you to Mr Mintah, whose generosity and compassion will forever be etched in my heart. In those moments of despair, your kindness became my lifeline – thank you so much. I also extend my dedication to my siblings, Justice and Eukeria, whose constant encouragement lifted my spirits when I needed it most. A million thanks goes to Priscilla who got me back on my feet in the most difficult times, and I will never forget those moments. To the "adjakpakpo boys" - Emmanuel, Kingsley, Kofi, and Mustapha - your wise counsel and support were invaluable in maintaining my sanity throughout this journey. Big thanks to Auntie Felicia for whipping up those mouthwatering omotuo specials and an array of delightful 'home-chos' just for me! I extend heartfelt appreciation to Angela Nunana, Aline, Brown, Joel, Jesslord, Stella, Adrian, Albert F., Nana Yaw (SI), Mckenzie, Claudette, Angela Kazadi, Baaba, Pastor Young, Bro Yaw, and the entire Pentecost International Church for providing me with a second home in Sweden, where I found solace and community. Lastly, I am thankful to everyone I have encountered in my life, whose influence has shaped me from childhood to this moment. To all who have offered assistance in any capacity, your contributions are deeply appreciated, and I pray for abundant blessings upon you.

Albert Duodu
Lund, April 2024

Introduction

Introduction

We cannot solve our problems with the same thinking we used when we created them.
— Albert Einstein

The latest report from the Intergovernmental Panel on Climate Change (IPCC 2023; see also Lewandowsky et al. 2019; Cook 2019) paints a stark picture: our planet is running a fever. This ongoing climate crisis will have substantial as well as unpredictable effects on the conditions for human life, for example by leading to extreme weather events, rising sea levels that prevent habitation in many of the world's most populous areas, elimination of sensitive species which threatens the functioning of wider ecosystems, and much more. It is not controversial to state that the climate crisis is a major challenge for mankind (Burgess et al., 2017; Carleton et al., 2022; Kelley et al., 2015).

The good news is that we have witnessed a significant decrease in emission intensity within the manufacturing sector of many developed countries. One possible explanation is technological expansion. However, another possible explanation is that the production of pollution-intensive goods (and thus emissions) might have shifted towards countries with less stringent policies, i.e., carbon offshoring. Without environmental policy harmonization, this will lead to a concept called carbon leakage. The first paper delves into this issue and provides causal evidence and a mechanism through which carbon offshoring could occur and how it translates to lower emission intensities for firms. However, the connection between trade and carbon emissions is complex. In my second paper *(joint with Zouhier El-Sahli)*, we aim to innovate upon the current literature by examining how local import competition exposure, *defined at different spatial dimensions within Sweden*, could affect local firms' environmental behavior. We also delve into the underlying mechanisms of this effect, which include productivity spillovers, adjustments in production strategies by manufacturers (such as shifting towards cleaner product mixes), and changes in pollution abatement investments. Interestingly, when countries implement policies to mitigate the adverse environmental effects of trade, these measures can have economic consequences. In my third paper, I examine how changes in energy prices due to energy tax shocks affect Swedish firms' environmental and economic outcomes. This allows me to evaluate the trade-off, or otherwise, of the effect of embarking on ambitious climate policies.

Overall, this thesis aims to make contributions to two major economics fields – environmental economics and international economics. First, it aims to contribute to our understanding of how globalization, broadly defined, affects the environment through firms' changing behavior. Second, it seeks to investigate how climate policies affect economic outcomes, such as the location of production, wages, employment and inflation.

Throughout the thesis, a great emphasis will be put on methodological soundness, using causal estimation techniques, and basing the conclusions based on micro-level evidence with the help of a very rich dataset on Swedish manufacturing firms. By adopting this approach, I aim to provide insights that are not only theoretically grounded but also empirically supported by the data. In the following section, I provide a bird's eye view of my data and methodology used in this thesis. This allows us to appreciate the depth and breadth of the analysis, providing a solid foundation for drawing meaningful conclusions about the environmental and economic impacts of trade and energy price shocks on Swedish manufacturing firms.

1 Data and Methodological overview

1.1 The Swedish Firm-Level Data

As a nation renowned for its environmental consciousness, Sweden serves as an intriguing backdrop for my studies. To explore the intricate interactions between trade, energy prices, the environment, and the economy, I have tapped into extensive firm-level datasets meticulously collected over the period 2005-2014 by Statistics Sweden – the government agency responsible for official statistics in Sweden. The reliability and quality of this data are widely acknowledged to be very high, given that misreporting is punishable by law. In the following subsections, I offer a glimpse into this rich tapestry of data.

Environmental variables. In most empirical research on the environment and climate, obtaining firm-level emission data with such granularity is challenging. Typically, emissions are sourced and utilized at the industry and national levels. This limitation arises because the technology for capturing CO_2 emissions at their source is often unavailable in many firms. One workaround for this data challenge involves gathering data on all energy types used by firms and calculating their CO_2 emissions based on the types of fuel they use. In this context, I gather information on the energy usage of all manufacturing plants with 10 or more employees. Subsequently, I compute CO_2 emissions from fuel inputs using the CO_2 content of these energy sources.

Additionally, this dataset is enriched by Statistics Sweden's reporting on a subset of firms (approximately 600 per year), detailing their expenditures and investments in pollution abatement. I have access to this valuable data spanning the years 2005 to

2014. Therefore, I have goldmine of environmental variables at my disposal, providing a rich foundation and a direct test of how trade can affect the environmental behaviour of firms.

Another distinctive feature of my dataset is the inclusion of firm-level annual expenditures on and quantities of purchased energy. This facet offers a unique opportunity to compute the unit value of energy for each firm, which is typically not readily available for research on carbon and energy prices (Dechezleprêtre and Sato, 2020). Given that I can compute energy prices at the firm level, I can equally observe energy price shocks and the policy environment surrounding these events and examine how this has impacted firms environmental performance and competitiveness.

Production and Trade. Another important aspect of my dataset is the rich data on firms' production and trade activities. In particular, I obtain production and trade data from two important databases from the SCB. First, from the Production of Commodities and Industrial Services (IVP) database, I access annual information detailing the quantities and values of production at the 8-digit product levels of about 6,200 manufacturing firms in Sweden. Second, I access trade data from the International Trade in Goods (ITG) database. This database provides detailed country and product trade information for all Swedish firms, encompassing values and quantities of imports and exports at the 8-digit product level. This level of detail in the import data is what enables me to construct a shock in trade activities of firms using a shift-share style instrument (see subsection 1.2). This approach allows me to illustrate how different types of imports ('dirty' vs 'clean') impact the environmental practices of manufacturing firms.

Economic variables. To complement the aforementioned data and highlight distinct features of the firms in my dataset, I obtain firm-level economic variables from the Structural Business Statistics database (FEK). This database offers a plethora of firm-level variables, including the number of employees, industry classification, and balance sheet variables such as sales, assets, investments, and other production costs. Additionally, I utilize this data to estimate firms' total factor productivity (TFP) following the methods proposed by Wooldridge (2009) and Levinsohn and Petrin (2003), as well as firms' markups following the method proposed by De Loecker et al. (2016). Detailed explanations of these methodologies can be found in paper 3, appendix B.

1.2 Methodology

Armed with these panel datasets, I conduct a comprehensive firm-level analysis of the impact of trade and energy prices on changes in two key phenomena over time: firms' emissions and economic variables such as TFP, employment, and prices. To help clarify the estimation techniques used in this thesis, let's consider an example from my first paper, where I aim to understand how changes in carbon imports over time affect firms' emissions. To do this, I specify a linear regression model where

emission intensity (emission per sales) is the dependent variable and carbon imports is the explanatory variable. An important question of identification is whether carbon imports may be biased by a self-selection issue, where only certain types of firms, such as dirty, large, and less-productive firms, engage in carbon imports. Additionally, certain important variables, such as alternative emission-saving technology, technical changes in firms, and climate policy shocks, which are unobservable, may also bias such a relationship. This phenomenon gives rise to what is termed the omission variable bias.

To overcome this issue, econometricians and applied statisticians recommend the use of controls and high-dimensional fixed effects for both time periods and firms or even industries and regions. This helps to deal with factors specific to each case or time period that might otherwise be overlooked and hence reduce the risk of committing inferential error. However, a rapidly growing amount of literature in causal inference has shown that fixed effects regressions could not control for all omitted variables: it could deliver consistent estimates only with strong assumptions about the homogeneity of treatment effects, and may be biased when treatment effects vary over time or by firms (Cengiz et al., 2019; De Chaisemartin and d'Haultfoeuille, 2020; Sun and Abraham, 2021; Goodman-Bacon, 2021; Callaway and Sant'Anna, 2021; Borusyak et al., 2022c). Therefore, my measure of carbon imports, which largely depends on import demand of Swedish importers, may still suffer from endogeneity issues, even after using high-dimensional fixed effects. For example, firms may be encouraged to import dirty intermediate goods if their emissions are high and vice versa. Hence, changes in supply and demand conditions may feed into each other, which would lead to reverse causality.

Shift-share instruments. To mitigate these concerns and estimate the causal effects of carbon import, I must isolate the supply-driven increase in imports (components that are caused by arguably exogenous increases in trade). Following Hummels et al. (2018) and recent discussions by Goldsmith-Pinkham et al. (2020), Borusyak et al. (2022a) and Borusyak et al. (2022b), I use global supply shocks directed to countries other than Sweden and its neighbouring countries as instruments. Think of these shocks as exogenous policies and/or non-policies that affects the exporting products at source countries. For instance, suppose Ghana were to implement export promotion policies that result in increased imports of certain products. This would cause supply shocks for Swedish importing firms of these products.

Thus, my identification strategy requires yearly data on world export supply from source countries, which I obtain from the UN COMTRADE database on bilateral trade. These data, available at the 6-digit HS level, allows me to match them with my firm import data. First, I calculate the world export supply of the product, excluding the supply to Sweden and its immediate neighbouring countries (Denmark, Finland, Germany, and Norway). I expect this variation in the world export supply to be positively correlated with the imports of Swedish firms, as it reflects changes in the relative price and quality of the product in the exporting countries. To make the instrument specific to a particular importing firm and product at a particular time, we multiply the world export supply of the product by the pre-sample share of the

product in the total imports of the importing firm. The resulting firm-time specific instrument is calculated as follows:

$$IV_{it} = \sum sh_{fjc} WX_{jct};$$

where WX_{jct} is the world supply of product j by country c at time t and sh_{fjc} is the pre-sample share of product j imported from country c by the domestic importing firm f. I use pre-sample shares to create an exposure for the specific products imported before entering the sample and also ensure that the input use of the importing firm is not influenced by current technology shocks.

The instrument is valid if it satisfies the standard exclusion restriction. That is, the instrument must be randomly assigned. But an identification under shift-share instruments does not fully require such strict assumption. As explained in Goldsmith-Pinkham et al. (2020), Borusyak et al. (2022a) and Borusyak et al. (2022b), the exogeneity of shift-share instruments can stem from the exogeneity of either the shares or the shocks. In the "shares view", we would need to assume that unobserved determinants of imports and emissions are unrelated to the choice of initial product offerings of firms, conditional on industry trends. This assumption seems unlikely in my context. Indeed, any product-specific trend would violate the assumption. For instance, import competition has been shown to increase productivity in Swedish manufacturing (Akerman et al., 2021). Thus, firms heavily specialized in products with low trade restrictions over the period would likely have grown faster than other firms, even without the supply shocks. Instead, I adopt the view that foreign supply shocks are as good as randomly assigned with respect to firm outcomes, after controlling for industry trends. This is a less restrictive requirement which simply argues that the instrument will be valid if the world export shocks are uncorrelated with the average firm-level characteristics that determine emissions (Borusyak et al., 2022b). The identifying assumption is that firms did not sort into industries such that the industry characteristics were correlated with the emissions and the import and export shocks. One example of problematic sorting would be if firms that increased their imports systematically, operated in sectors that experienced an increase in emissions and productivity. To address sorting of this kind, I include firm fixed effects and sector-year fixed effects. In some specifications, I add lagged information on firm capital, employment, investment in machines, and the amount of emission rights purchased as additional controls.

Dynamic Difference-in-Difference. Given the quasi-random assignment of shocks, the primary concern regarding identification is the possibility of unobservable firm characteristics influencing the trend of firm-level outcomes and being correlated with the shocks. For instance, firms with more robust market research departments may be better equipped to identify and capitalize on growing foreign markets with laxer environmental policies, leading to independent reasons for their accelerated growth in dirty imports. Also, large multinational firms could influence exporting policies of emerging markets which could mechanically correlate with positive foreign supply shocks. If omitted variables are linking expanding firms to growing foreign markets,

we would expect to observe distinct trends among firms that are projected to experience larger dirty imports in the future, even prior to the the shocks. To overcome this empirical issue, I follow Barrows and Ollivier (2021) by employing a dynamic difference-in-differences using current-year-weighted foreign supply shocks as instrumental variables, while controlling for arbitrary industry-by-year trends. Additionally, I instrument these shocks with base-year-weighted shocks and inspect how the pre-trends changes prior to and after the export shocks. This specification has the advantage of assessing the pre-trends and estimating cumulative long-run impact of carbon offshoring on emissions.

The remainder of this introduction provides a short summary of each arm of the thesis, outlining the motivation, empirical strategy and results.

2 Summary of Papers

2.1 How does globalization affect the environment?

My first line of research focuses on the intricate link between globalization and the environment. Globalization, marked by the massive movement of goods, services, capital, and information across borders, has been praised for spurring economic advancement. However, it has also been implicated in exacerbating environmental degradation, raising questions about its sustainability and equity implications. As globalization progresses, it's becoming clearer that the burden of environmental risks isn't evenly shared, with marginalized communities and regions facing a "double exposure" from the negative impacts of globalization and global environmental change (Leichenko and O'Brien, 2008; Thorpe and Figge, 2018). The emergence of pollution offshoring – a phenomenon where carbon-intensive production relocates to countries with less stringent environmental regulations – has added a new layer of complexity to this discourse.

Paper I: "Carbon Offshoring and Manufacturing Cleanup". In recent decades, high-income countries as a group have managed to grow their economies without emitting more pollution. In theory, offshoring could explain this achievement (Baumert et al., 2019; Copeland et al., 2022; Levinson, 2023; Ferguson and Sanctuary, 2019). However, assessing the extent to which high-income countries reduce domestic pollution by importing goods whose production generates foreign pollution is methodologically challenging because it requires an extensive data at the micro level, including product level decisions, imports and emissions and some exogenous variation in offshoring. As a result, there is a lack of causal evidence on this issue. Against this backdrop, this thesis first explores how pollution offshoring might have contributed to the green transition of the manufacturing sector in developed countries. My first paper deepens our understanding of the mechanism through which pollution offshoring can occur at firm-level and how it may have lead to the lower emissions of Swedish manufacturing firms.

Before describing the problem with pollution offshoring, it is worth being clear about what is meant by each word: "pollution" and "offshoring". Pollution in this context could be referred to as "emissions," which, according to popular perception, are typically considered as outputs. However, in economics terms, pollution is an input . Manufacturing a product for sale often requires pollution, just as it requires capital and labor. Goods can be manufactured using more pollution and less capital and labor, or less pollution and more of those other inputs. As for offshoring, economists sometimes describe it as "outsourcing," which occurs at the firm level, when a particular firm contracts with a third party to purchase goods or services – either a final or intermediate inputs – that were previously produced or could have been produced by the firm's own employees (Levinson, 2023). In this thesis, I use "offshoring" in the more stricter sense, to describe what happens when a firm in a country imports intermediate and/or own-produced goods rather than producing them domestically.

What is wrong with pollution offshoring? Take for example, a firm that produces more than one good (e.g. iWatch, iPhone etc.) and uses intermediate inputs (e.g. Tin, beryllium, mercury, phthalates etc.). This firm has the option to source these intermediate goods either locally or by importing them from abroad. When an intermediate input is both emission-intensive and locally produced, it becomes an integral part of firm's production process, contributing to higher emissions. If these emissions surpass a predetermined regulatory threshold, the firm can expect to incur environmental penalties, such as higher carbon taxes (Cole et al., 2014). In order to circumvent such environmental penalties, the firm may choose to import these emission-intensive intermediate goods from foreign markets, provided that the cost of importing is more economical than the cost of implementing emission-reduction measures. Thus, the decision of offshoring hinges on the fact that importing these goods from countries with a comparative advantage in emission-intensive production and a more lenient environmental regulatory framework can offer a cost-effective solution. The concern is that pollution offshoring can lead to the so-called "carbon leakage" — where local emissions are moved elsewhere, thereby undermining national climate policies as well as efforts to invest in green innovation and technologies aimed at reducing emissions.

By exploring the causal mechanisms underlying pollution offshoring and its implications for firm-level emissions intensity, my first paper seeks to shed light on the validity of carbon leakage concerns and the efficacy of policy interventions aimed at mitigating environmental externalities in a globalized world.

In particular, the paper examines the carbon offshoring behavior of Swedish manufacturing firms from 2006 to 2014 using detailed data on production, trade, and emissions. For my empirical purpose, I use firm-specific instruments based on importing emission-intensive goods from countries with less stringent environmental policies. This instrument leverages changes in these countries' export composition to predict shifts in intermediate and final goods imports. Because the shocks are quasi-randomly assigned, my main concern about identification is whether hidden qualities of firms could affect how their emissions trend over time and be linked to the shocks. Thus, I complement my instrumental variable approach by employing a difference-

in-difference strategy with weighted foreign supply shocks as instrumental variables, while controlling for firm and industry-specific trends (Barrows and Ollivier, 2021; Borusyak et al., 2022b; Goldsmith-Pinkham et al., 2020; Hummels et al., 2018).

The main conclusions of the study are threefold. First, I estimate that in a year where carbon content of input import are 10% higher than it typically is for that firm, we would expect production-based CO_2 emission intensity to fall by 5.3%. However, the elasticity is small when the type of good imported is firm's own-produced good. While there is a positive impact on average production-based emissions, my findings indicate that this is somewhat offset by an increase in transportation emissions. Therefore, it remains uncertain what the net effect on emissions will be. My second set of results show that environmental policy arbitrage may play a role this effect. Offshoring to countries with weaker environmental regulations led to a relatively larger reduction in emissions intensities, with this effect being particularly pronounced in low-income countries. Thirdly, I find that cleanups are larger for multi-product firms, cleaner industries and multinationals.

The paper makes three key contributions to the literature on manufacturing cleanups. Firstly, it extends previous findings from France and the U.S. to Sweden, demonstrating that carbon offshoring reduces emissions at the firm level (Dussaux et al., 2023; Najjar and Cherniwchan, 2021; Levinson, 2010; Li and Zhou, 2017). These studies have overly focused on how firms production-based emissions change as a result of climate policies and trade. My paper, on the other hand, examines the impact of offshoring on both production-based and transport-based emissions, revealing a trade-off where production-based emissions decrease while transport emissions increase.

Secondly, the study contributes to micro-level research on globalization and the environment by quantifying the carbon offshoring channel of trade shocks on emissions. My paper distinguishes between different types of imported goods and finds that carbon offshoring through input reallocation leads to a larger reduction in emissions compared to in-house offshoring. Additionally, it shows that dirty imports do not solely account for improved environmental impact, but other forms of globalization such as outward FDI could contribute to lower emission intensity of firms (Akerman et al., 2021; Dussaux et al., 2023; Leisner et al., 2023; Kander et al., 2020; Li and Zhou, 2017; Shapiro and Walker, 2018; Ferguson and Sanctuary, 2019).

Thirdly, the paper explores the role of environmental policy arbitrage, demonstrating that firms' importing or migration to countries with lax environmental policies significantly impacts their emission intensity. Using a comprehensive index of environmental policy stringency, it provides a rigorous comparative analysis of offshoring to/from countries with different environmental policies, highlighting the importance of considering environmental policy differences in understanding manufacturing cleanup dynamics (Cole and Elliott, 2005; Cole et al., 2014; Stavropoulos et al., 2018; Koziuk et al., 2019).

Paper II: "Local Import Competition and Firm-level Emissions" *(joint with Zouheir El-Sahli):* Yet, the relationship between trade and carbon emissions is com-

plicated. Existing literature suggests that import competition can drive efficiency improvements in firms. However, it remains uncertain whether such gains translate into better environmental practices by these firms. In the second paper, we show that globalization via localized import competition exposure could be beneficial. Here, we carefully isolate the carbon leakage concern associated with increasing global integration by focusing on how spatially localized import competition shocks affect the environmental performance of local non-offshoring upstream producers.

We innovate upon the current literature, which typically measures import competition at the national level with the assumption that competition increases simultaneously and symmetrically within an economy as soon as an imported product crosses the border. Instead, we argue that manufacturers are increasingly involved in interconnected firms through complex global value chains (GVCs), where firms supply each other with intermediate goods. Consequently, trade shocks will have a more pronounced impact on producers in close proximity to importers, as the shock is relatively contained within a region/locality due to geographical and/or industrial frictions. Thus, we contribute to the literature on import competition by examining the role of proximity in buyer-seller networks and the spatial positioning of firms in studies focusing on domestic competition.

Using detailed geographical information about the location of all manufacturing firms in Sweden during the period 2005-2014, we find evidence that import competition leads to lower CO_2 emission intensity and this result is robust to several import competition measures defined at different geographic dimensions. We then proceed to examine the channels that explain this result. We find evidence that import competition leads to an increase in firm productivity. Hence, emission intensity decreases because the firm becomes more energy-efficient through gains made in productivity. In addition, we find that the producing firm increases the production of its core product while also increasing markups. This suggests that the firm differentiates itself by upgrading the quality of its production while focusing on its core product. Because product upgrading is likely to involve cleaner capital investments, emission intensity also decreases. This is further supported by evidence that import competition also leads to higher intensity in investment in emissions abatement technology.

This study contributes to the literature on buyer-seller networks, emphasizing the importance of proximity in firms' marginal cost, production, markup, and labor market outcomes. Previous research by Gullstrand and Knutsson (2019); Bellone et al. (2016); Autor et al. (2013); Ding et al. (2016) highlights various dimensions of import competition and its effects on firms. However, little is known about import competition's effects on firms' emissions and production processes at the local level. Our analysis fills this gap by examining the spatial dimension of import competition's effects on firms' emissions.

Additionally, our study aligns with research on trade and the environment, particularly studies by Akerman et al. (2021) and Leisner et al. (2023), which focus on how offshoring affects the emission intensity of firms. While these studies focus on importing firms, our paper explores the impact of trade shocks on producing firms in

Sweden's spatial dimensions, aiming to understand the role of geographical frictions in firms' responses to import competition.

Furthermore, our study connects to the literature on firm-level productivity and abatement. Research by Newman et al. (2023); Bernard et al. (2019) highlights the importance of technology adoption and product mix in firm-level changes in productivity. Our analysis complements these studies by estimating the effects of import competition on emission intensity at the firm level and directly testing the technological channel using abatement investment data.

2.2 Economic Implications of Stringent Climate Policies

The looming climate crisis has catapulted climate change higher up on the global policy agenda. However, when countries aim to address the negative environmental consequences of trade, those policies may, in turn, have economic repercussions. If the costs of greening the economy are perceived to render firms less competitive, increase unemployment, and be unfairly distributed, this could undermine the success of the transition. Against this backdrop, it is crucial to better understand the economic effects of climate policy.

While there is mounting evidence on the effectiveness of such policies for emission reductions (e.g. Martin et al. 2014; Andersson 2019) less is known about their economic effects. A key transmission channel of carbon pricing policies operates through higher energy prices (Fabra and Reguant, 2014). Because energy demand is relatively inelastic, at least in the short term, this reduces the profits of firms and households. A relatively energy intensive firms tend to spend larger share of their profits on energy and energy-related products and will disproportionately be affected. In order to maintain competitive, this may affect their employment of non-energy inputs such as labour and capital. As such productivity of firms may fall. Additionally, higher energy prices also affect the economy indirectly through second-round effects via prices and wages and hence income and employment. These indirect effects may also be borne unequally across society.

In my second line of research, I explore these consequences. I assess the contemporaneous and dynamic effect of energy price shock in a unified empirical framework to be able to attribute any potential differences in energy price to energy tax design in Sweden. Specifically, I estimate a panel model of Swedish manufacturing firms and identify the effects of energy price by controlling for global and local macro-financial conditions in addition to firm and industry-fixed effects. I use both instrumental variables and dynamic DID approaches (see e.g., Goldsmith-Pinkham et al. 2020; Borusyak et al. 2022a; Barrows and Ollivier 2021) to measure the effect of an increased energy price on environmental goals (i.e. energy consumption and emissions) and economic goals (i.e., firm productivity, employment, and output prices). In doing so, my study bridges two critical aspects often studied separately in public finance and environmental economics: the interplay of energy substitution with other inputs

and the pass-through of input costs. Ultimately, I evaluate the trade-off between the environmental benefits and economic costs of energy prices.

The analysis uses data on 3800 firms with with 10 or more employees and observed during 2006-2014. The paper shows that: (i) even though a 10% increase in energy prices causes a decline in energy use by 8.6% at the firm level, this increment has negative effect on net employment at the firm level, but it motivates a reallocation of production and workers from energy-intensive to energy-efficient firms. (ii) I also find that low-productivity firms are potentially at high risk of reduced productivity, while high-productivity firms continue to experience productivity growth. Overall, the results indicate that an increase in energy prices leads to a crowding-out effect. This means that regardless of whether it enhances energy efficiency or not, a higher energy price hinders other possible productivity improvements in firms. (iii) Lastly, I show varying responses among different types of firms in adjusting their unit prices. Specifically, energy-intensive firms absorb a greater percentage of the cost increase and pass on a smaller portion of the marginal cost increase to consumers. Consequently, the increase in carbon costs leads to an incomplete pass-through of marginal costs to consumers.

The study makes three main contributions. Firstly, it adds to the existing body of research on the environmental effects of carbon policies, particularly focusing on energy pricing. While previous studies have shown evidence supporting the effectiveness of carbon policies at the macro-level (national and sector level), there is limited understanding of how these policies affect emissions at the micro-level, such as firm-level emissions. While some exceptions exist, such as studies by (Martin et al., 2014) and (Martinsson et al., 2022) that demonstrate carbon policies can reduce emissions significantly at the firm-level, this study contributes to the micro-level evidence by providing new causal estimates based on firm-level energy prices. The methods employed in this study, including shift-share instruments and dynamic DID techniques, allow for the isolation of exogenous variations in firm-level energy prices and assessment of both short- and long-term impacts.

This paper contributes to the literature on the economic effects of climate policy by examining both macroeconomic impacts and microeconomic effects on the labor market. While some studies find no significant macroeconomic effects of carbon taxes (Bernard and Kichian, 2021; Konradt and Weder, 2021; Metcalf and Stock, 2020), others identify potential costs such as lower output and higher unemployment (Känzig, 2023). The study adds to this by investigating how energy prices impact labor demand, revealing that firms may substitute high-skilled costly labor for low-skilled cheap labor (Marin and Vona, 2021). Additionally, it explores the relationship between energy prices and firm productivity, contributing to existing research in this area (Andersson, 2020; Dechezleprêtre et al., 2017; Venmans et al., 2020). Furthermore, the study examines the potential for carbon leakage induced by higher energy prices, offering insights into firms' sourcing decisions for inputs and complementing studies such as Ferguson and Sanctuary (2019), who provides valuable insights into firms' import behavior in response to electricity price changes. Overall, the paper contributes to understanding the complex economic effects of energy prices.

This paper also contributes to the cost pass-through literature by examining how manufacturing firms adjust prices in response to energy price changes. It finds that higher energy prices may reduce firms' international competitiveness, but not all firms adjust their prices accordingly. Factors such as productivity levels, multi-product structures, and regulatory status influence firms' ability to absorb energy price inflation. This study's findings align with Ganapati et al. (2020), who examined energy cost pass-through in U.S. manufacturing industries. However, this study extends the analysis to both single and multi-product firms and explores various heterogeneous effects, shedding light on the complexities of pricing and cost-sharing behaviors among different types of firms.

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