

Closer and greener? Firms' global value chain participation and sustainability

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Index of abbreviations

CIS	Community Innovation Survey
CMIE	Centre for Monitoring Indian Economy
CSR	Corporate Social Responsibility
EI	Environmental Innovation
EPS	Environmental Policy Stringency
GHG	Greenhouse gas
GVC	Global value chain
IEA	International Energy Agency
IfW	Kiel Institute for the World Economy
IPCC	Intergovernmental Panel on Climate Change
KCG	Kiel Centre for Globalization
NAFTA	North American Free Trade Agreement
PPML	Poisson pseudo maximum likelihood
SDG	Sustainable Development goal
WIOD	World Input-Output Database

Chapter 1

Introduction

The year 2015 was a pivotal year for global sustainable development. By agreeing on the 2030 Agenda for Sustainable Development and the Paris Agreement, the global community committed to sustainable development at all levels of governance. Unquestionably, both agreements are an urgent call for sustainable development, including actions related to social and environmental domains. It is now the responsibility of all countries to ensure that the stated goals are reached. At the heart of the Paris Agreement is the objective to hold “the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels” (Paris Agreement, 2015, p.3). A failure of this goal would cause tremendous climate-related hazards to ecosystems and humans. Among many others, these include losses in biodiversity, physical water scarcity, an increasing number of extreme weather events, more widespread diseases such as dengue, a rise in sea levels threatening coastal areas and even entire countries and an increased pressure on food production and access (IPCC, 2022). Even facing these tremendous consequences, it seems as if the world is far off-track reaching the goal to limit global warming to well below 2°C. Nevertheless, any effort to limit global warming is desirable, as many climate-related risks increase disproportionately with rising temperature (IPCC, 2022). The fact that the global community still has a long way to go is shown, for example, by the development of CO₂ emissions over time. Figure 1.1 illustrates the development of CO₂ emissions from fossil fuels over the last two centuries split by world region.

Between 2019 and 2020, global CO₂ emission decreased slightly from 36.7 billion tonnes to 34.81 billion tonnes. However, this can be explained by the economic slowdown related to the global COVID-19 pandemic. In general, the figure shows that global CO₂ emissions continue to rise and have not yet peaked. Between 2000 and 2020, CO₂ emissions increased by 38% from 25.23 billion tonnes to 34.81 billion tonnes. Copeland et al. (2022) emphasise that most emission growth originates from developing and emerging countries. This pattern is also visible in the figure. Undoubtedly, China is the elephant in the room. China’s CO₂ emissions increased by an astonishing 210% from 3.44 billion tonnes in 2000 to 10.67 billion tonnes in 2020. In 2020, China announced its target to peak CO₂ emissions by 2030 and achieve carbon neutrality before 2060 (International Energy Agency, 2021a). These targets require China to decouple its development from emissions at an earlier stage of development than other advanced economies in the past, including the US, which has historically been the largest contributor to global CO₂ emissions. Even as India walks in China’s footsteps, its successes in green transformation set the pace for

Annual CO₂ emissions from fossil fuels, by world region

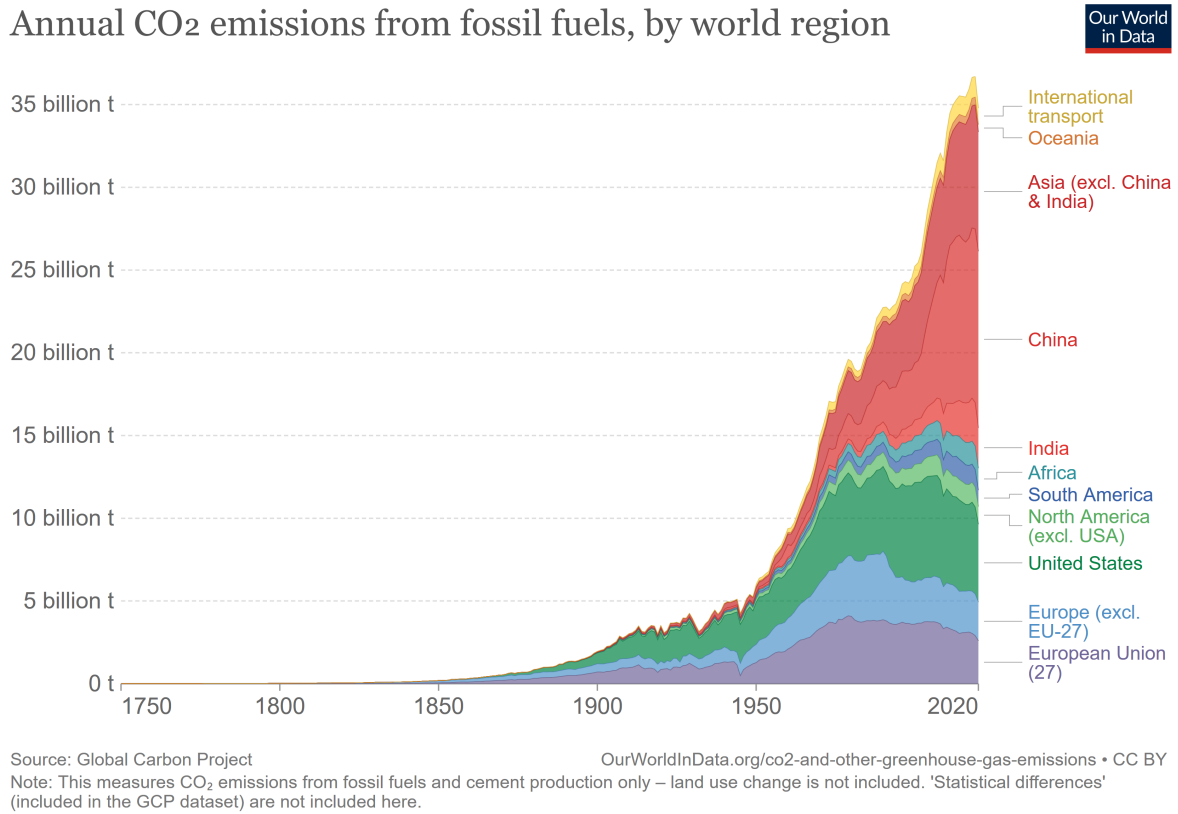


Figure 1.1: Graphical illustration by Ritchie et al. (2020) of the global CO₂ emissions from fossil fuels split by region based on data of the Global Carbon Budget (2021)

the world to tackle climate change. India's CO₂ emissions increased by 149% from 0.98 billion tonnes to 2.44 billion tonnes between 2000 and 2020. As a result, India is now the third largest emitter of CO₂ emissions, although its per capita emissions are significantly lower compared to the historical major emitters in Europe and North America. All in all, the increase in emissions in India and China illustrates that global success in combating climate change is urgently needed not only in industrialised countries but also in emerging and developing countries. At the same time, emerging and developing countries are especially vulnerable to the risks of climate change (IPCC, 2022). Addressing climate-related risks poses additional challenges to developing countries than they already face in addressing social-related sustainable development goals, such as eradicating poverty and hunger, improving education and achieving health and well-being.

In this doctoral thesis, I focus on the role of firms to reach sustainable development. More precisely, I contribute to the understanding of how firms' global value chain (GVC) participation relates to their sustainability, covering environmental and social performance. GVCs are a mechanism, where firms from different countries are connected by the transfer of goods, capital and workers. These countries, in turn, are characterised by different stages of development and patterns of technology, knowledge and legislation relating to social and environmental aspects. Several studies show that GVC participation, such as by exporting, can be accompanied by improvements in the environmental performance of firms (e.g., Batrakova and Davies (2012);

Forslid et al. (2018); Girma and Hanley (2015); Richter and Schiersch (2017)). Among other things, I contribute to the literature by analysing how the characteristics of firms' country of origin and the country to which a firm is linked through participation in GVCs, moderate the respective relationship between GVC participation and sustainable performance.

Certainly, understanding the relationship between firms' GVC participation and sustainability is only one part of a complex network of how economic activity relates to sustainable development. In their flagship report, the World Bank (2020) outlined the rise of GVCs after the 1990s and how it contributed to growth, jobs, and the reduction of poverty. On the one hand, the report points to environmental degradation, such as outsourcing dirty production steps to countries with weak environmental regulation stringency. On the other hand, they emphasise that GVC participation might lead to technology transfer, the upgrading of standards and the transmission of intangible assets, such as good managerial practices. Overall, I follow Copeland et al. (2022) who emphasise the importance for decision makers of understanding the complex relationship between globalisation and the environment.

Chapter 2, 3 and 4 analyse how firms' GVC participation relate to improvements in environmental performance.¹ The diffusion of clean technologies and the related green transformation of industries is directly linked to the Paris Agreement and SDGs 9 and 12. The International Energy Agency (2021b) emphasises that the technologies needed to achieve the necessary deep cuts in global emissions by 2030, already exist. What is missing is an immediate and massive deployment of clean and energy-efficient technologies, already deployed or available in industry. The transmission of these technologies is especially important for firms based in developing and emerging countries, characterised by being - on average - further away from the technology frontier (Gutiérrez and Teshima, 2018). As outlined before, developing and emerging countries represent the main source of emission growth, are more vulnerable to climate risks and need to decouple economic growth from environmental degradation at an earlier stage of development than advanced economies.

To begin with, in Chapter 2, I summarise the relevant empirical literature on the relationship between firms' GVC participation and environmental performance.² By discussing the related literature, the literature review also presents the main contributions of Chapter 3 and Chapter 4. At the core of the literature review is a discussion of two relatively separate literature strands. Applying insights from both literature strands, I identify nine key findings and possible research gaps. The first literature strand, starts with the seminal contribution by Grossman and Krueger (1991), focusing on the impact of trade on the environment. It is followed by many other contributions, using aggregated-data (Grossman and Krueger, 1995; Chichilnisky, 1994; Copeland and Taylor, 1994; Antweiler et al., 2001). More recently, studies using firm level data have been gaining momentum (Cherniwchan, 2017). By using firm level data, re-

¹Please note that the writing style of each chapter differs due to the different requirements of the journals to which the manuscripts have been submitted.

²The chapter is an earlier version of "Semrau, F. O. (2023). "Chapter 8: Firms' global value chain participation and its environmental performance: a review of the empirical literature." Handbook on Innovation, Society and the Environment edited by Edited by Fernando J. Díaz López, Massimiliano Mazzanti, and Roberto Zoboli, 125-139." The published manuscript is accessible via <https://doi.org/10.4337/9781802200065.00016>. Since the chapter includes a detailed discussion of the literature relevant for the Chapters 3, 5 and 4, it substitutes to some extent the literature review typically part of an introduction.

searchers can account for firm level heterogeneity even in narrowly defined industries (Melitz, 2003). In addition, they can analyse different forms of GVC participation and environmental performance. GVC participation includes export status (e.g., Batrakova and Davies (2012); Forslid et al. (2018); Richter and Schiersch (2017)), import competition (e.g., Cherniwchan (2017); Gutiérrez and Teshima (2018)), foreign ownership (e.g., Brucal et al. (2019); Eskeland and Harrison (2003)) and GVC positioning (e.g., Semrau (2022)). Environmental performance includes mainly efficiency-related domains such as energy consumption or emissions per unit of sales. The literature widely agrees that there is a positive relationship between firms' GVC participation and environmental performance. The second literature strand goes beyond these efficiency arguments by focusing on the adoption of environmental innovations. Environmental innovations are innovations that are new to the firm and outperform available alternatives in terms of environmental impact (Kemp and Pearson, 2007). The results are more diverse. The reasons for these diverse findings are discussed and for instance include local embeddedness, countries' idiosyncrasies and the sample under investigation (e.g., Cainelli et al. (2012); Del Río et al. (2016); Ghisetti et al. (2015); Hanley and Semrau (2022)).

Chapter 3 focuses on firms' export activity and how it relates to the adoption of environmental innovations.³ It includes an empirical analysis of how the relationship between environmental innovation differs between different types of innovation and how home country and export market characteristics moderate the relationship. To this end, we use the Community Innovation Survey, which includes firm level data from 14 European countries. By applying Logit and Poisson pseudo-maximum likelihood estimations, we reveal that firms' export activity positively relates to the adoption of environmental innovation in Europe's laggard economies. However, a similar relationship is not observable in Europe's relatively wealthier countries. In line with prior studies, the sample is limited to innovation-active firms, contributing to the understanding of what drives a firm's decision to adopt green innovation, or not. Prior studies mainly focus on advanced economies and find that exports foster innovation activities, but do not determine whether a firm's innovation can be characterised as green or not (e.g., Cainelli et al. (2012, 2015); Chiarvesio et al. (2015); Del Río et al. (2016); De Marchi and Grandinetti (2012); Kafourous et al. (2008); Peñasco et al. (2017)). In addition, we categorise environmental innovations into process- and product-based innovations and reveal that the positive relationship is exclusively driven by process-based innovations. Moreover, we add environmental policy in the export destinations as an additional factor, influencing a firm's decision regarding the adoption of environmental innovation. To this end, we develop a measure that captures the exposure to environmental policy stringency, proxying the demand for environmental upgrading in export destinations. Our empirical results show that exposure to environmental policy in export destinations positively relates to environmental innovation adoption. The latter is observable for all countries in the sample and indicates that export-related learning-by-exporting, regulation-push and demand-pull relate to firms' decisions regarding environmental performance. Even though there is much heterogeneity in terms of development within the sample of firms in European countries, it rather takes the perspective of advanced economies on a global scale.

³The chapter has been published as Hanley and Semrau (2022) accessible via <https://doi.org/10.1080/13662716.2021.2021865>.

By focusing on India, I turn the spotlight to a developing country in Chapter 4.⁴ Thereby, I use the Indian firm level Prowess database to empirically analyse whether firms occupying upstream positions - being positioned closer to the raw product - emit disproportionately more CO₂, in absolute and relative terms. Based on aggregated data, Shapiro (2021) illustrates that upstream industries produce dirtier compared to firms closer to the final product. I bring this insight to the firm level, opening opportunities to analyse how firm characteristics moderate the relationship. Most notably, I analyse whether exposure to environmental regulation in export destinations acts as a modifier of the relationship. A firm's GVC position is the main variable of interest. Similar to Herkenhoff et al. (2021), I combine the Prowess database with WIOD and calculate a firm's GVC position by regarding a firm's product-mix.⁵ By additionally considering the product-mix, I modify the approach of Hanley and Semrau (2022), capturing a firm's exposure to environmental regulation in export destinations. The dependent variable is a firm's CO₂ emissions in absolute and relative terms. Based on Barrows and Ollivier (2018, 2021), I calculate a firm's direct CO₂ emissions in a respective year. The approach uses information on firms' physical energy consumption and converts this into yearly CO₂ emissions in production. Such a level of detail is rare in the context of developing or emerging countries. To derive CO₂ intensity, I divide the CO₂ emission by the value added and sales of the relevant firm, respectively. The main specification is an OLS estimation, controlling for established drivers of the firm's clean production. In addition, I apply a 2-SLS instrumental variable approach to verify the robustness of the results. The main finding confirms Shapiro (2021), revealing a negative relationship between upstreamness and CO₂ emissions. A change in upstreamness corresponding to switching from the *textiles* industry to the *basic metals* industry results in an increase of CO₂ per unit of value added by around 35%. Beyond this main finding, I reveal that exposure to environmental regulation abroad negatively moderates the relationship. Interestingly, for firms in very upstream positions, the relationship even disappears completely. This finding links to the adoption of environmentally friendlier production standards, an aspect especially important for firms in upstream positions aiming to remain competitive in international markets.

In the last Chapter, I focus on Corporate Social Responsibility (CSR) along GVCs.⁶ CSR is defined as spending to comply with social and environmental standards which exceed domestic legal requirements (McWilliams and Siegel, 2001). Accordingly, and in contrast to the chapters before, Chapter 5 focuses on firms' social performance additionally to environmental performance. The adoption of CSR relates to SGD 8 on decent work and economic growth as well as SDG 12 on responsible consumption and production. With a theoretical model and an empirical analysis, the research contributes to the understanding of the drivers of CSR spending along the GVC. The analysis focuses on suppliers of intermediates located in the Global South and serving markets in the Global North. Firms serving these markets might face higher standards compared to firms only serving the domestic market. CSR spending along the GVC is characterised by incomplete contracts because such spending is observable, but not verifiable

⁴The chapter builds on Semrau (2022).

⁵The approach is discussed in more detail in the executive summary of Chapter 5 below.

⁶The chapter is an earlier version of "Herkenhoff, P., Krautheim, S., Semrau, F. O., & Steglich, F. (2024). "Corporate Social Responsibility along the global value chain". *Journal of Development Economics*, 167, 103236." The article is accessible via <https://doi.org/10.4337/9781802200065.00016>.

(Boehm and Oberfield, 2020; Hart and Moore, 1999). Our theoretical model shows that suppliers can differentiate their products by spending on CSR and by doing so contribute to products finally being sold to ethically concerned consumers. We find that accumulated CSR spending in upstream stages, incentivises buyers of intermediates to invest in CSR. This pattern leads to an increasing profile of CSR spending with diminishing distance to final consumption along the GVC. We analyse this main prediction empirically. To this end, we combine the Indian Prowess database with the World Input-Output Database (WIOD, Timmer et al. (2015)). We use the approach developed by Antràs et al. (2012) and Antràs and Chor (2018) to calculate the time-varying GVC positioning of Indian industries. We merge this industry-level information on GVC positioning, with detailed information on a firm’s product-mix. By doing so, we derive a firm’s individual GVC positioning varying with industry-specific changes and firms’ decisions on its product-mix, such as changes in the product portfolio or relative sales. By constructing a firm-specific GVC measure, we build on Newman et al. (2018) who analyse how GVC participation relates to CSR activities in Vietnam. They emphasise the role of GVC positioning and control for it by including industry fixed effects. However, the fixed effects are not time-varying and do not allow for an interpretation of how the GVC position relates to CSR activities. In our empirical specifications, we analyse whether the GVC position relates to firms’ CSR spending. The results strongly support the conjecture that firms in downstream positions spend more on CSR. In terms of magnitude, the predicted CSR spending is around 56% higher for very downstream firms compared to very upstream firms. Our results indicate that policymakers aiming to foster CSR spending should place more attention on upstream positions. First, firms in upstream positions spend - on average - less on CSR. Second, additional CSR spending by suppliers in the upstream stages is followed by an increased incentive for downstream firms to invest in CSR.

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Chapter 2

Firms' global value chain participation and its environmental performance - A review of the empirical literature^{* †}

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Abstract

Global diffusion of previously developed clean and energy efficient technologies is continuing to define the pace of the international transition to a green economy over the next few years. Empirical firm-level analyses offer a powerful approach to investigate how a firm's global value chain participation relates to the adoption of green technologies. In this chapter, I review insights referring to two relatively separated strands of literature. First, scholars from the international economics literature provide strong evidence for an environmental efficiency premium from exports, foreign direct investments and proximity to final consumption. Second, scholars analysing the determinants of environmental innovation adoption go beyond efficiency arguments and cover a diverse set of environmental domains. Results from the latter are ambiguous and crucially depend on the sample under investigation. I conclude the review with the identification of nine key findings and a discussion of possible research gaps.

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2.1 Introduction

Immediate and massive deployment of already developed clean and energy efficient technologies crucially define the pace for deep cuts in global emissions by 2030 (International Energy Agency, 2021). Veugelers (2012) emphasises the urgency to run a clean innovation machine at full speed in the light of the sizeable climate challenge we face. Global diffusion of the available green technologies is necessary to reach full steam ahead in the green economic transition, e.g. reducing greenhouse gas emissions and other environmental negative impacts.

In this chapter, I review empirical research on how firms' global value chain participation, including exports, foreign ownership, positioning along a global value chain and indirect exposure to international trade via import competition, is associated with firms' environmental performance. In so doing, I identify nine key findings and discuss possible remaining research gaps.

Overall, the impact of globalisation on the environment is ambiguous (Cherniwchan et al., 2017; Copeland et al., 2022). The empirical use of firm-level data offers a powerful approach to better understand the interface between globalisation and the environment, since it enables researchers to account for the heterogeneity of firms, even in narrowly defined industries (Cherniwchan et al., 2017; Melitz, 2003).¹

Summarising two main strands of empirical literature forms the core of this chapter. Scholars part of the first literature strand, I characterise as belonging to the international economics literature, frequently adopt the perspective of the Melitz (2003) model to analyse induced effects caused by global value chain participation. These effects include energy consumption, CO₂ emissions and emissions from other pollutants. Scholars from the second literature strand emanate from the innovation literature. Here, the focus is on external and internal factors driving a firm's decision to adopt environmental innovation and green management tools.² Surprisingly, both strands of literature are relatively unconnected. Accordingly, matching theoretical and empirical frameworks represents a promising avenue for future research.

The international economics literature widely agrees on firm-level environmental efficiency gains induced by different forms of global value chain participation and exposure to trade such as exports, import competition, foreign acquisition and proximity to final consumption (e.g. Batrakova and Davies (2012); Brucal et al. (2019); Cherniwchan et al. (2017); Gutiérrez and Teshima (2018); Semrau (2022)). Conversely, the results on how a firm's global value chain participation links to the diffusion of environmental innovation is less clear-cut and results depend on factors such as local embeddedness, the idiosyncrasies of a firm's home country, the type of environmental innovation and whether non-innovative active firms are excluded from the empirical analysis (e.g. Cainelli et al. (2012); Del Río et al. (2016); Ghisetti et al. (2015); Hanley and Semrau (2022)). Some aspects, like positioning in a value chain or import competition are

¹Analysing the whole effect of trade on the environment goes beyond the scope of this literature review. To this end, I refer to a very recent contribution on globalisation and the environment by Cherniwchan et al. (2017) and Copeland et al. (2022).

²I follow Ghisetti and Pontoni (2015) and use the term environmental innovation rather than eco-innovations. Even though many scholars use the terms synonymously, eco-innovations were initially conceived as a subclass of environmental innovations, affecting a firm's economic and environmental performance. Environmental innovation, per se, limits the focus to a firm's environmental performance.

widely neglected so far. The next section discusses the stated research strands in more detail.

2.2 Firms' global value chain participation and environmental efficiency in production

The discussion on how trade affects the environment goes back to the seminal contributions of Grossman and Krueger (1991), Grossman and Krueger (1995), Chichilnisky (1994), Copeland and Taylor (1994), Antweiler et al. (2001) and Frankel and Rose (2005). Generally, the aggregated effects of trade on the environment can be split into a scale-, composition- and technique effect. First, trade increases the scale of economic activity that translates into a higher environmental footprint. Second, trade liberalisation can shift the place of production in line with a country's comparative advantage that has an ambiguous effect on the environment. Third, the technique effect refers to trade-related changes in the environmental costs of production, e.g. driven by the adoption of more efficient machinery and equipment. Theoretical predictions on the total effect of trade on the environment depend on the determinants of a country's comparative advantage (Cole and Elliott, 2003). Accordingly, empirical investigation needs to be guided by our current understanding regarding the environmental impacts of globalisation. In this chapter, I widely limit the discussion to empirical analyses based on firm-level data.

Global value chains involve splitting production processes across different countries and allows firms to specialise in tasks. The Melitz model predicts that more productive firms self-select into exporting (Melitz, 2003). Bustos (2011) extends the theoretical model of Melitz to technology choice and predicts that export-related increases in revenues enables exporters to upgrade technology, e.g. increase spending on computers, software, technology transfers, patents, and innovation activities. The proposed mechanism is empirically shown for Argentinean firms for the period 1992 to 1996, a period characterised by a sharp drop of tariffs between Argentina and Brazil due to the trade liberalisation of MERCOSUR.

Batrakova and Davies (2012) apply the theoretical predictions to environmental-related outcomes, more precisely to energy consumption of Irish manufacturing firms between 1991 and 2007. They find that export entry is positively connected with energy use, while it is negatively associated with energy intensity. Interestingly, they distinguish between high and low energy consumers. In particular high energy consumers can offset higher energy demand by efficiency gains.

Cui et al. (2016) analyse the relation between export and environmental performance for U.S. firms in 2002, 2005 and 2008. They find that more productive firms report lower emission intensities (sulphur dioxide (SO₂), carbon monoxide (CO), ozone (O₃) and totals suspended particulates (TSPs) per value of sales). Conditioned on firms' productivity, exporting firms environmentally perform better compared to firms only serving the domestic market.

Richter and Schiersch (2017) find evidence supporting an exporter's environmental efficiency premium - measured as CO₂ productivity. The used German firm-level data span the period 2003 to 2011 and contain detailed information on a firm's fuel consumption that allows for a calculation of direct CO₂ emissions from production. They find that an increase in export

intensity by one percentage point, leads to average CO₂ emission efficiency gains by 0.22%.

Forslid et al. (2018) theoretically and empirically shed light on the mechanism as for how a firm's export activity relates to CO₂ efficiency when emissions are subjected to an environmental tax. After export entry, firms scale-up production in order to meet foreign demand. This scaling-up of production enables firms to spread fixed production costs across an increased number of units. Incentivised by exposure to environmental policy regulations, the fixed costs of abatement can also be allocated among more units, increasing the attractiveness of investments in CO₂ efficiency. They back up their theoretical predictions with empirical evidence using data of Swedish manufacturing firms for the time period 2004 to 2011.

Holladay (2016) employs data concerning toxic chemical emissions from U.S. manufacturing establishments, for the period 1990 to 2006. He finds that exporters generate less pollution emissions compared to non-exporters from the same industry once output levels are considered in the equations. In an additional finding, he reveals that import competition reduces the domestic prices of varieties and drives the least productive and more pollution-intensive establishments out of business.

Shapiro and Walker (2018) show that between 1990 and 2008 the air pollution emissions from the U.S. manufacturing sector decreases by 60% - primarily driven by within-product changes in emission intensity induced by environmental regulation rather than on changes in productivity or trade. However, Cherniwchan (2017) focuses on effects related to trade liberalisation and finds empirical evidence for a clean-up of the U.S. manufacturing induced by the North American Free Trade Agreement (NAFTA). For the period 1994 to 1998, he finds that nearly two-thirds of the reduction of particular matter (PM₁₀) and sulphur dioxide (SO₂) emissions can be attributed to the trade liberalisation. The effect is driven by two main sources, namely improved export opportunities to the Mexican market and improved access to imports from Mexico. The latter effect is relatively larger in magnitude and indicates a high importance of import competition for the clean-up of firms' environmental performance.

Kong et al. (2022) point to a bias in the literature towards using firm-level data from developed countries and investigate the firm-level environmental effects related to the Chinese WTO accession in 2001 – a date that allows them to label China as a developing country and emphasising substantial differences between developing and developed countries. They find that the trade liberalisation significantly reduced firms' toxic emissions - including sulfur dioxide (SO₂), soot and dust, nitrogen oxide (NO_x) - through the scale of production, export opportunities, technology upgrading, intermediate input and within-firm mechanisms.

Gutiérrez and Teshima (2018) build on Cherniwchan (2017) and manifest the positive environmental effect of import competition. They combine Mexican plant-level and satellite imagery data for the time period 2000 to 2003 and emphasise that firms in developing countries can benefit disproportionately from trade-related positive impacts on technological choice. This is because these firms are on average further removed from the technological frontier or best management practices. Their key results reveal that import competition increases energy efficiency, but is likely to induce a decrease in abatement expenditures. This latter prediction suggests a technology uptake, reducing the need for expenditure on abatement. They also argue that the literature on global value chain participation and environmental efficiency is biased towards

developed countries. A key reason for this bias is the availability of data containing concrete and reliable measures of environmental performance at the firm-level.

The Indian firm-level Prowess data represent a popular source for investigations into several empirical aspects of international economics (e.g. De Loecker et al. (2016); Goldberg et al. (2010a,b); Topalova and Khandelwal (2011)). As a rare feature in the context of developing countries, the data cover panel information on a firm's energy inputs. This allows researchers to calculate the direct CO₂ emissions embodied in production, similar to the approach used by Richter and Schiersch (2017) or Forslid et al. (2018) for firms from developed countries. Barrows and Ollivier (2018) even apply the methodology at the product-level, investigating how a firm's product-mix affects the intensity of CO₂ emissions. They find that emission efficiency decreases with distance to the core competency, where core competency is proxied by the product with the highest sales rank. Exporters are likely to sell their core competency on foreign markets, but more productive firms are also able to diversify their foreign sales and these products may indeed be dirtier compared to products characterised by the core competency. To this end, firm-level analysis on environmental efficiency that fails to account for changes in the product-mix, can be misleading. In line with this, Barrows and Ollivier (2021) contribute a further study to shed light on within-product CO₂ efficiency gains. They find that increasing foreign demand induces exporters to scale-up production and induces efficiency gains at the product-level. The latter finding can be interpreted as a technique effect, strongly backing prior findings that export activity links to environmental gains following the adoption of clean technologies.

Martínez-Zarzoso et al. (2020) analyse the relation between exports and energy consumption of Indian firms between 1987 and 2016. This period covers India's 1991 economic liberalisation and accession to the WTO in 1995. In line with prior analyses, they find that exporters spend more on energy, but their production can be characterised as energy efficient. In particular, firms from high energy consuming industries can incorporate trade-related efficiency gains. These high energy users are more likely to be located in an upstream position along the global value chain, bringing them relatively closer to the raw material of a value chain (Semrau, 2022; Shapiro, 2021). A negative correlation between energy consumption and selling finished goods indicates such a pattern at the Indian firm-level Martínez-Zarzoso et al. (2020). However, global value chain positioning does not comprise the core of the main analysis. Additionally, the measure of global value chain positioning does not account for the global value chain positioning of products sold as intermediates.

Antràs et al. (2012) and Antràs and Chor (2018) show how World Input-Output tables can be used to calculate a country's industry global value chain positioning in a respective year. This measure considers sales directly sold to final consumers and the proximity to final consumption of sales sold as intermediates. By applying the respective global value chain measure, Shapiro (2021) reveals an environmental bias of trade policy: Upstream industries emit substantially higher levels of CO₂ per unit of output, while facing lower trade tariffs. The pattern between CO₂ and upstreamness is somewhat monotone and can be observed over a wide range of different countries. Generally, upstream processes are more energy and capital demanding, e.g. the extraction of raw materials from the ground and downstream stages disproportionately use labour as a direct input, which is generally cleaner. International trade policy serves as

an indirect subsidy for these dirty industries, since upstream industries successfully lobby for reduced tariffs in order to reduce input costs. Based on Shapiro’s findings, Copeland et al. (2022) state as a stylised fact on trade and the environment the pattern that dirty industries are more likely to be upstream.

Semrau (2022) analyses the relation between upstreamness and dirty production using the Indian Prowess database. By doing so, he applies the global value chain measure of Herkenhoff et al. (2021), who take the industry-level global value chain measure to the firm-level. He finds that once controlling for different firm characteristics, upstream firms tend to require more energy, emit higher levels of CO₂ and demonstrate reduced efficiency for both measures. There are alternative explanations for the pattern going beyond Shapiro (2021). First, consumer awareness for environmentally friendly energy and CO₂ efficiency production might increase with proximity to final consumption (Zhu et al., 2012). Second, once firms observe that prior stages have already made investments in the production of inputs perceived as ethical, firms are incentivised to contribute to a cleaner final product (Herkenhoff et al., 2021). Interestingly, the negative relation between upstreamness and clean production reduces with increased exposure to environmentally demanding export markets. In line with Gutiérrez and Teshima (2018), the latter links to higher distance from the technological frontier or best management practises for firms occupying an upstream position.

Foreign ownership represents another direct form of global value chain participation, characterised as a particular form of a firm’s export strategy. Horizontal foreign direct investments can serve as a substitute for exports. Additionally, vertical foreign direct investments can be viewed as a sub-set of a firm’s internationalisation strategy, fragmenting production across different countries (Antràs and Yeaple, 2014).

Foreign ownership is seen as a powerful force for convergence in productivity and production technologies (Arnold and Javorcik, 2009). The literature on foreign ownership and environmental performance dates back to Eskeland and Harrison (2003), who analyse whether multinationals flock to developing countries, characterised as pollution havens due to lax environmental policy stringency. However, they find weak evidence that foreign investors are more likely to target sectors with high levels of air pollution. Conversely, they find that foreign firms in Mexico, Morocco, Côte d’Ivoire and Venezuela produce environmentally more efficiently, compared to domestic firms.³ Generally, empirical results on the relationship between firms’ environmental performance and ownership are rather mixed (Cole et al., 2017).

Cole et al. (2008) analyse Ghanaian firm-level data to investigate if training-related capacity building for key employees, transfers from parent companies to their foreign affiliates. They find that training of key decision makers in the affiliates does improve efficiency in fuel, energy and electricity use. However, there is no direct link between foreign ownership and fuel use nor energy use, except some indication for a switch to a higher share of electricity consumption, on average being a cleaner input compared to alternative fuels used.

³The following analysis limits to the latter observed effect on the relation of foreign ownership and a firm’s environmental performance. However, it should be noted that these neglects possible exploitation of parent firms based in advanced economies facing stringent environmental regulation and might exploiting lax environmental regulations in less-advanced economies. The latter is for instance shown by Hanna (2010) by employing panel data of US firms.

In a more recent study, Brucal et al. (2019) apply a difference-in-difference approach combined with propensity score matching to Indonesian firm-level data. They show that acquired plants increase energy demand, but reduce energy intensity by about 30% two years following acquisition. Additionally, they find similar results for a firm’s CO₂ intensity. They interpret the results as suggesting an association between foreign acquisition and improvements to production processes arising through the adoption of better technologies or better management.

The studies discussed so far find evidence suggestive of an environmental premium from global value chain participation or exposure. Export activity, import competition, downstream position and to some extent foreign ownership relate to environmental efficiency gains. However, the research reviewed so far, predominantly focuses on efficiency measures of energy, CO₂ and other emissions. But the concept of environmental innovation covers a diverse set of environmental domains (Kemp and Pearson, 2007). The next section connects these results with a relatively independent literature on the drivers of environmental innovation adoption by a firm.

2.3 Firms’ global value chain participation and environmental innovation adoption

Based on the Oslo Manual, most scholars investigate the drivers of environmental innovations defined as innovations that result in a reduction of the environmental impact in consumption or production and are novel to the firm (OECD and Eurostat, 2005; Kemp and Pearson, 2007; Del Río et al., 2016).

Building on Rennings (2000) and Jaffe et al. (2005), it is well-established that the drivers of environmental innovation and standard innovation adoption differ. Horbach (2008) categorises the determinants of environmental innovation adoption into a supply side technology-push, a demand-pull, environmental regulation-push and other firm specific factors (Barbieri et al., 2016; Ghisetti and Pontoni, 2015). Variables that capture the extent of a firm’s internationalisation, e.g. foreign ownership or export activity, are contained in the list of firm-specific drivers. However, the results for these variables are ambiguous and remain controversial.

Empirical studies that capture a firm’s export activity as a determinant of environmental innovation adoption, to a large extent, do not report any positive correlation (Cainelli et al., 2012; De Marchi and Grandinetti, 2012; Horbach et al., 2013; Peñasco et al., 2017). The results by Chiarvesio et al. (2015) confirm that export activity does not induce any environmental upgrading. Additionally, they also control for the direction of trade and do not find a positive impact if exports target non-emerging countries. The authors claim that lack of a significant correlation between export activity and environmental innovation adoption might be an artefact of the data - namely the geographic restriction of their study and other similar prior studies to advanced European countries such as Italy, Spain, Germany or France. These countries are characterised by a high level of consumer awareness and environmental policy stringency.

Keshminder and del Río (2019) partly address this research imbalance, even though their analysis is restricted to the chemical sector in Malaysia. Their findings suggest that foreign stakeholders influence a firm’s environmental strategy, including efforts to comply with foreign buyers’ demand and environmental regulation. Moreover, firms can benefit from knowledge

spillovers. Sanni (2018) runs a comprehensive analysis on the drivers of environmental innovation adoption for Nigerian firms, including a discussion on the importance for firms from developing countries to comply with international standards. However, the empirical analysis does not include measures of a firm’s global value chain participation.

Besides the empirical bias towards single-country studies in advanced countries, Ghisetti et al. (2015) point to a strong focus on innovative active firms that also affects the generalisability of any study findings. Kafouros et al. (2008) claims that a firm’s export activity allows the firm to tap into knowledge created in different markets, pushing the firm’s innovative capacity. Accordingly, and in line with the theoretical literature of Melitz (2003) and Bustos (2011), the sub-sample of innovative firms is more likely to be active in foreign markets as well as to report higher productivity that itself links to a better environmental performance (Cainelli et al., 2015; Hanley and Semrau, 2022; Shapiro and Walker, 2018).

Girma and Hanley (2015) use an instrumental variable approach to assess the drivers of environmental innovation adoption for firms based in the United Kingdom. They do not restrict the sample to innovative firms and find robust evidence for a firm’s export activity and its adoption of environmental innovation. Ghisetti et al. (2015) restrict the sample to innovative firms and exploit a multi-country dataset, covering a broad range of Eastern European countries. Interestingly, the reported correlation between a firm’s export status and the likelihood of environmental innovation adoption is positively significant, but they do not investigate this correlation in more detail. However, Ghisetti and Pontoni (2015) argue that export activity does not directly relate to a firm’s environmental innovation adoption but rather moderates R&D activity as part of a firm’s technology-push. Conversely, Hanley and Semrau (2022) argue for a direct relationship, pointing to the literature on trade induced knowledge-flows and learning-by-exporting (De Loecker, 2007). Generally, the adoption of environmental innovation requires firms to source knowledge beyond their own boundaries (De Marchi, 2012; Cainelli et al., 2015). The argument is that trade induced knowledge flows are relatively more important for firms based in catch-up economies, facing reduced access to knowledge due to deficiencies in the domestic knowledge base or in labour force skills. By exploiting a cross-country sample and running a split focusing on Eastern European countries, Hanley and Semrau (2022) show that exporters are more likely to adopt process-based environmental innovations. These results are in line with Horbach (2016) who reveals empirical indication for knowledge flows from West to East Europe. Additionally, the results echo Peñasco et al. (2017) who claim that international drivers are more important for firms based in countries with lower levels of domestic demand for environmental upgrading.

Emphasising the importance of regulation for environmental innovation adoption (Ambec et al., 2013; Borghesi et al., 2015; Brunnermeier and Cohen, 2003; Porter and Van der Linde, 1995), Hanley and Semrau (2022) also investigate the role of the direction of trade, exploiting the OECD Environmental Policy Stringency index to proxy foreign demand for environmental quality (Botta and Koźluk, 2014). They find that higher export exposure to more environmentally stringent markets increases both, the likelihood of any environmental innovation adoption as well as the number of environmental innovations adopted. The positive correlation is observable for product- and process-based environmental innovations and indicates that firms incorporate

foreign stakeholders' demand into their production decision.

Del Río et al. (2016) point to lack of studies in the innovation literature focusing on foreign ownership as driver of environmental innovation adoption. This is somehow surprising, since foreign ownership is shown to foster a firm's process and product innovation activities. The latter effect goes beyond a mere selection effect, the cherry-picking of foreign investors who might be tempted to acquire the most productive firms within any industry (Guadalupe et al., 2012). Moreover, and similar to export activity, foreign direct investments relate to direct knowledge spillovers, an important driver for firms' environmental innovation adoption (Javorcik, 2004; Arnold and Javorcik, 2009; De Marchi, 2012).

However, Peñasco et al. (2017) do not find that Spanish firms with foreign equity are more likely to adopt environmental innovations. The missing finding for foreign direct investment is similar to evidence produced by Inoue et al. (2013) who, for a sample of Japanese firms, find no positive correlation between having a head office in a foreign country and the introduction of quality standards. Similarly, Cainelli et al. (2012) use Italian firm-level data and do not find evidence for a significantly positive correlation between foreign direct investment and environmental innovation adoption. However, they find that foreign-owned firms are more likely to implement environmental innovations if they are embedded in local production systems, e.g. by cooperation to suppliers or universities. Conversely, Cainelli et al. (2015) find at least some indication of a positive correlation between firms experiencing foreign investment flows and the adoption of environmental innovations. However, the effect is only significant at the ten-percent level.

As similar to the remarks relating to the interface between export activity and environmental innovation adoption, the composition of the samples used by researchers might explain the different results. Albornoz et al. (2014) use Argentinean firm-level data to investigate if foreign-ownership influence firms' environmental actions. They find foreign-owned firms show compared to domestic firms' higher activities in the adoption of six out of eight environmental measures. Also, Kannen et al. (2021) analyse data from non-advanced countries. They extend the data coverage to a cross-country sample containing firms from Eastern Europe, Africa and Asia at different stages of development. They find that foreign direct investment positively correlates with the implementation of a green management, measured as the adoption of a green manager or green strategy, and show that green management go hand in hand with better environmental performance, e.g. higher environmental innovation adoption rates. By directly measuring the link between foreign ownership and green management, they pin down the mechanism of improved management practices suggested by Brucal et al. (2019) on how a foreign ownership relates to a firm's environmental performance. Such a relation between foreign ownership and green management is also observable for other environmental-related management routines. For instance, Zhu et al. (2012) explore Chinese survey data from 2006 and find that ISO 14001 environmental management certification is more likely adopted in foreign owned firms.

Summing up, there is a distinct lack of consensus in the literature on foreign ownership and environmental innovation, suggesting more work remains to be done. The final section summarises the main results of the literature review and connects the findings to gaps in the literature.

2.4 Main results and conclusion

The global diffusion of clean energy efficient technologies will continue to define the success (or otherwise failure) of sustainable development over the next decade. This chapter provides a comprehensive overview how global value chain participation of firms interacts with their environmental performance. Two main strands of the literature have expanded significantly over the previous 15 years. The first strand, theoretically and empirically focuses on efficiency, with implications for the environment. Specifically, efficiencies relating to energy consumption, CO₂ emissions and emissions of other pollutants. The second strand, broadens the coverage of different environmental domains, with a focus on the determinants of environmental innovation adoption.

I identify nine main results, before discussing possible paths for future research:

1. With export entry, firms scale-up their production, increasing their environmental footprint. However, environmental efficiency gains offset part of this increase (e.g. Barrows and Ollivier (2021); Batrakova and Davies (2012); Cui et al. (2016); Forslid et al. (2018); Holladay (2016); Martínez-Zarzoso et al. (2020); Richter and Schiersch (2017))
2. Import competition induces environmental efficiency gains at the firm-level (e.g. Cherniwchan (2017); Gutiérrez and Teshima (2018))
3. Energy and CO₂ demand and efficiency, vary substantially between different value chain positions, with upstream industries and firms reporting the dirtiest production (e.g. Copeland et al. (2022); Semrau (2022); Shapiro (2021))
4. Foreign-owned firms produce more energy and more CO₂ efficiently compared to their domestic counterparts (e.g. Brucal et al. (2019); Eskeland and Harrison (2003))
5. The relation between the global value chain participation of firms and environmental innovation adoption requires an own theoretical framework going beyond the standard innovation model or environmental efficiency measures (e.g. Horbach (2008); Kemp and Pearson (2007); Rennings (2000))
6. Exports foster innovation activities in advanced economies, but do not determine if a firm's innovation can be characterised as green or not (e.g. Cainelli et al. (2012, 2015); Chiarvesio et al. (2015); Del Río et al. (2016); De Marchi and Grandinetti (2012); Kafourous et al. (2008); Peñasco et al. (2017))
7. Exporters based in catch-up economies are more likely to adopt (process-based) environmental innovations compared to non-exporters (e.g. Hanley and Semrau (2022); Keshminder and del Río (2019))
8. Regulation represents a major driver of environmental innovation adoption (e.g. Ambec et al. (2013); Borghesi et al. (2015); Brunnermeier and Cohen (2003); Porter and Van der Linde (1995)). Apart from the domestic standards for environmentally friendly production that confronts a firm, it must also incorporate foreign demand into its production decision (e.g. Hanley and Semrau (2022); Keshminder and del Río (2019))

9. The findings relating to the relation between foreign ownership and environmental innovation adoption are controversial (e.g. Cainelli et al. (2012); Chiarvesio et al. (2015); Peñasco et al. (2017)), while a positive relation is observable in less-advanced countries (e.g. Albornoz et al. (2014); Kannen et al. (2021)) and local embeddedness positively associates with environmental innovation adoption rates (Cainelli et al., 2012)

Overall research on a firm’s global value chain participation and environmental performance has grown rapidly over the last decades. However, the literature on environmental innovation adoption builds mainly on cross-sectional data. One possible improvement would be to use panel data, introducing the possibility for researchers to apply firm identifiers, tracking the firms across time and allowing the application of more sophisticated econometric techniques to deal with issues of firm-heterogeneity and selection. Second, details of export destination or origin of foreign investments would enable further investigation into the mechanism by which global value chain participation relates to environmental innovation adoption, e.g. foreign demand-pull vs. regulation push or the importance of knowledge flows for a firm’s step-up to cleaner production. Third, the country coverage of empirical studies is still biased towards European countries that are relatively advanced on a global scale. On balance, future research should contribute to the understanding of environmental innovation adoption in less-advanced economies (Del Río et al., 2016; Sanni, 2018). These countries are increasingly important hubs of the global emission growth (Copeland et al., 2022), more reliant on external knowledge flows and facing less domestic environmental regulation (Hanley and Semrau, 2022; Horbach, 2016). Additionally, the environmental innovation literature mainly focuses on environmental innovation adoption and not on environmental innovation that is new to the market. However, the latter variants of environmental innovation are highly important for reaching net-zero emissions beyond 2030 (International Energy Agency, 2021). But there are difficulties that hamper any investigation into the drivers of these innovation with a greater degree of novelty, since some of these innovations do not survive long (Del Río et al., 2016; International Energy Agency, 2021). Also, the lack of empirical consensus regarding the importance of foreign ownership, necessitates further investigation, e.g. the role of different kinds of environmental innovation. Finally, the future research might add to our understanding how global value chain positioning and import competition relate to environmental innovation adoption.

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Chapter 3

Stepping up to the mark? Firms' export activity and environmental innovation in 14 European countries* †

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Abstract

We investigate the ability of exports to trigger the adoption of environmental innovation (EI) in firms, shedding light on the determinants of convergence in environmental standards for Europe's catch-up economies. To analyse this question empirically, we measure the latter as the 1) probability a firm adopts EI and the 2) breadth of EI adoption in firms. Applying Logit and Poisson pseudo-maximum likelihood estimations to firm-level data for 14 European countries, we find that particularly Eastern European exporters report higher EI adoption propensities, an effect exclusively driven by process-based EI and not observable for product-based EI. Additionally, we reveal that regardless of a firm's origin, exposure to importing countries with high market-related environmental policy stringency, is linked to the adoption of EI. We conclude that learning-by-exporting, regulation-push and demand-pull mechanisms may help to explain these findings, with foreign markets being characterised by a wider diversity of stakeholder preferences.

JEL Classification Numbers: F18, O31, Q52, Q56

Keywords: Green-/Eco-/Environmental innovation; Circular economy; Environment and trade; Export activity; Green Deal

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3.1 Additional appendix

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Description of dependent variable

As described in Section 3.1, the harmonised Community Innovation Survey (CIS) waves 2008 and 2014 include an expanded list of environmental innovation (EI) variables. However, there are slight differences between both waves. Figures 3.1 and 3.2 present the exact questions used to create the dependent variables.

10. Innovations with environmental benefits

An environmental innovation is a new or significantly improved product (good or service), process, organizational method or marketing method that creates environmental benefits compared to alternatives.

- The environmental benefits can be the primary objective of the innovation or the result of other innovation objectives.
- The environmental benefits of an innovation can occur during the production of a good or service, or during the after sales use of a good or service by the end user.

10.1 During the three years 2006 to 2008, did your enterprise introduce a product (good or service), process, organisational or marketing innovation with any of the following environmental benefits?

	Yes	No	
<i>Environmental benefits from the production of goods or services within your enterprise</i>			
Reduced material use per unit of output	<input type="checkbox"/>	<input type="checkbox"/>	ECOMAT
Reduced energy use per unit of output	<input type="checkbox"/>	<input type="checkbox"/>	ECOEN
Reduced CO ₂ 'footprint' (total CO ₂ production) by your enterprise	<input type="checkbox"/>	<input type="checkbox"/>	ECOCO
Replaced materials with less polluting or hazardous substitutes	<input type="checkbox"/>	<input type="checkbox"/>	ECOSUB
Reduced soil, water, noise, or air pollution	<input type="checkbox"/>	<input type="checkbox"/>	ECOPOL
Recycled waste, water, or materials	<input type="checkbox"/>	<input type="checkbox"/>	ECOREC
<i>Environmental benefits from the after sales use of a good or service by the end user</i>			
Reduced energy use	<input type="checkbox"/>	<input type="checkbox"/>	ECOENU
Reduced air, water, soil or noise pollution	<input type="checkbox"/>	<input type="checkbox"/>	ECOPOS
Improved recycling of product after use	<input type="checkbox"/>	<input type="checkbox"/>	ECOREA

Figure 3.1: List of questions related to EIs covered in the harmonised CIS 2008

13. Innovations with environmental benefits

An innovation with environmental benefits is a new or significantly improved product (good or service), process, organisational method or marketing method that creates environmental benefits compared to alternatives.

- The environmental benefits can be the primary objective of the innovation or a by-product of other objectives.
- The environmental benefits of an innovation can occur during the production of a good or service, or during its consumption or use by the end user of a product. The end user can be an individual, another enterprise, the Government, etc.

13.1 During the three years 2012 to 2014, did your enterprise introduce a product (good or service), process, organisational or marketing innovation with any of the following environmental benefits?

	Yes	No	
	1	0	
<u>Environmental benefits obtained within your enterprise</u>			
Reduced material or water use per unit of output	<input type="checkbox"/>	<input type="checkbox"/>	ECOMAT
Reduced energy use or CO ₂ 'footprint' (reduce total CO ₂ production)	<input type="checkbox"/>	<input type="checkbox"/>	ECOENO
Reduced air, water, noise or soil pollution	<input type="checkbox"/>	<input type="checkbox"/>	ECOPOL
Replaced a share of materials with less polluting or hazardous substitutes	<input type="checkbox"/>	<input type="checkbox"/>	ECOSUB
Replaced a share of fossil energy with renewable energy sources	<input type="checkbox"/>	<input type="checkbox"/>	ECOREP
Recycled waste, water, or materials for own use or sale	<input type="checkbox"/>	<input type="checkbox"/>	ECOREC
<u>Environmental benefits obtained during the consumption or use of a good or service by the end user</u>			
Reduced energy use or CO ₂ 'footprint'	<input type="checkbox"/>	<input type="checkbox"/>	ECOENU
Reduced air, water, noise or soil pollution	<input type="checkbox"/>	<input type="checkbox"/>	ECOPOS
Facilitated recycling of product after use	<input type="checkbox"/>	<input type="checkbox"/>	ECOREA
Extended product life through longer-lasting, more durable products	<input type="checkbox"/>	<input type="checkbox"/>	ECOEXT

Figure 3.2: List of questions related to EIs covered in the harmonised CIS 2014

We define five process-based EIs by using the following variables:

- ECOMAT
- ECOENO, we combine ECOEN and ECOCO into a single variable in the CIS 2008
- ECOPOL, does also include water in CIS 2014
- ECOSUB
- ECOREC

In addition, we define three product-based EIs by using the following variables:

- ECOENU, does also include CO₂ footprint in CIS 2014
- ECOPOS
- ECOREA

Finally, we exclude two domains introduced in CIS 2014 from the analysis, namely ECOREP and ECOEXT.

Description of main independent variables

Section 3.2 describes the econometric strategy, including a discussion of the main independent variables: *export activity* and *EPS exposure*. Next, more details of these variables are presented.

Export activity

Figures 3.3 and 3.4 include the respective question used to define a firm's *export activity*. Both questions are widely similar between both survey waves.

1.2 In which geographic markets did your enterprise sell goods and/or services during the three years 2006 to 2008?

	Yes	No	
A. Local / regional within [your country]	<input type="checkbox"/>	<input type="checkbox"/>	MARLOC
B. National (other regions of [your country])	<input type="checkbox"/>	<input type="checkbox"/>	MARNAT
C. Other European Union (EU), EFTA, or EU candidate countries*	<input type="checkbox"/>	<input type="checkbox"/>	MAREUR
D. All other countries	<input type="checkbox"/>	<input type="checkbox"/>	MAROTH
Which of these geographic areas was your largest market in terms of turnover between 2006 and 2008? (Give corresponding letter)			LARMAR

*: Include the following countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.

Figure 3.3: Question used to define a firm's export activity in the harmonised CIS 2008

1.3 In which geographic markets did your enterprise sell goods and/or services during the three years 2012 to 2014?

	Yes 1	No 0	
A. Local / regional within [your country]	<input type="checkbox"/>	<input type="checkbox"/>	MARLOC
B. National (other regions of [your country])	<input type="checkbox"/>	<input type="checkbox"/>	MARNAT
C. Other European Union or associated countries* 4	<input type="checkbox"/>	<input type="checkbox"/>	MAREUR
D. All other countries	<input type="checkbox"/>	<input type="checkbox"/>	MAROTH
Which of these geographic areas was your largest market in terms of turnover during the three years 2012 to 2014? (Give corresponding letter)			LARMAR

*: Include the following European Union (EU) and associated countries: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, FYR Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.

Figure 3.4: Question used to define a firm's export activity in the harmonised CIS 2014

We denote three categories of a firm's export status. The first category applies if a firm does not serve foreign markets, so only MARLOC is selected. The second category *exporter* denotes a firm serving foreign markets but where the bulk of the firm's turnover are generated domestically. Accordingly, MARNAT, MAREUR or MAROTH are selected but no foreign geographic market is selected as largest market in terms of turnover (LARMAR). Finally, *export dominates* denotes that a foreign geographic market is selected as the largest market.

Environmental policy exposure

The OECD EPS Index is used to construct a proxy of a firm's exposure to foreign EPS. In so doing, we distinguish between market-related and non-market related EPS exposure. Overall, the OECD EPS Index includes 14 environmental policy instruments. Nine instruments are market-related and five instruments are non-market related (Botta and Koźluk, 2014). The raw data already includes variables capturing the respective market-related and non-market related EPS of a country. These variables are a weighted mix of the different policies. Market-related EPS allocates a weight of 0.33 to taxes, trading schemes and feed-in tariffs, respectively. The respective instruments considered are:

- Tax CO₂
- Tax Diesel
- Tax NO_x
- Tax SO_x
- Trading schemes CO₂
- Trading schemes green certificates
- Trading schemes white certificates
- Feed-in tariffs solar
- Feed-in tariffs wind

Non-market related EPS includes standards and R&D subsidies. To each policy a weighting factor of 0.5 is allocated and the respective instruments are:

- Emission limit values NO_x
- Emission limit values PM_x
- Emission limit values SO_x
- Sulphur content limit for diesel
- Renewable energy public RD&D budget

Table 3.1 includes the overall EPS ranking of the countries covered in the OECD EPS Index. The table is sorted by the EPS scores in 2006.

Table 3.1: OECD EPS scores sorted by the score in 2006

Year/Country	2006	2007	2008	2009	2010	2011	2012
France	3.28	2.86	2.90	3.69	3.15	3.70	3.57
Denmark	3.16	2.83	2.96	4.07	4.03	3.98	3.85
Finland	3.15	2.82	3.08	3.25	3.21	3.48	3.43
Sweden	3.03	2.70	2.92	3.34	3.09	3.23	3.10
Germany	3.00	2.67	2.64	3.06	3.02	3.14	2.92
Korea	2.96	2.96	3.38	3.52	3.52	3.44	2.63
Spain	2.96	2.75	2.70	3.00	2.72	2.85	2.22
Czech Republic	2.88	2.55	2.72	2.89	2.89	2.37	2.38
Austria	2.82	2.44	2.91	3.33	3.33	3.08	2.95
Netherlands	2.80	2.64	3.23	3.69	4.13	3.51	3.63
Italy	2.72	2.34	2.60	2.73	2.84	2.79	2.77
Portugal	2.71	2.21	2.26	2.47	2.54	2.27	2.13
Hungary	2.59	2.30	2.55	2.66	2.77	2.68	2.63
Belgium	2.40	2.20	2.34	2.58	2.60	2.53	2.47
United Kingdom	2.29	1.95	2.40	2.58	3.62	3.47	3.29
Poland	2.26	2.08	2.26	2.96	2.96	2.96	2.58
Ireland	2.23	1.71	2.05	2.16	2.22	2.43	2.05
Canada	2.17	3.27	3.31	3.85	3.35	3.67	3.42
Switzerland	2.13	2.13	2.67	3.19	3.33	3.29	3.29
Norway	2.13	2.05	2.34	3.19	3.19	3.19	3.26
United States	2.13	2.34	2.47	2.93	2.68	2.47	3.17
Australia	2.01	2.01	2.26	2.69	2.50	3.34	3.72
Greece	1.84	1.92	1.83	2.08	2.33	2.33	2.13
Slovak Republic	1.78	1.40	1.53	2.39	2.30	3.05	2.99
Japan	1.63	1.69	1.69	1.73	2.03	2.96	3.50
Turkey	1.50	1.50	1.50	1.54	2.06	2.21	1.83
China (People's Republic of)	0.77	0.77	0.81	0.98	1.10	1.35	2.04
India	0.67	0.63	0.63	1.13	1.20	1.26	1.30
Russia	0.65	0.65	0.60	0.60	0.60	0.60	0.60
South Africa	0.52	0.52	0.48	1.52	1.75	1.71	0.71
Indonesia	0.50	0.50	0.50	0.50	1.17	1.17	1.17
Brazil	0.42	0.42	0.42	0.42	0.42	0.38	0.38
Slovenia	n.a.	n.a.	1.64	1.85	2.46	2.42	2.28

Description: The OECD Environmental Policy Stringency (EPS) index is a country-specific and internationally-comparable measure of the stringency of environmental policy. Stringency is defined as the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behaviour. The index ranges from 0 (not stringent) to 6 (highest degree of stringency). The index covers 28 OECD and 6 emerging countries for the period 1990-2012. The index is based on the degree of stringency of 14 environmental policy instruments, primarily related to climate and air pollution (Botta and Koźluk, 2014). Version: 24.05.2018

Description of other independent variables

This part of the additional appendix complements Section 3.2 by providing more information how the independent variables are constructed using the CIS 2008 and CIS 2014 waves.

MNC captures a foreign ownership dummy. The dummy determines whether a firm belongs to an enterprise group with a headquarter located outside of the firm. For the construction, the following questions of the CIS 2008 and CIS 2014 are used:

1.1 In 2008, was your enterprise part of an enterprise group? (A group consists of two or more legally defined enterprises under common ownership. Each enterprise in the group can serve different markets, as with national or regional subsidiaries, or serve different product markets. The head office is also part of an enterprise group.) GP

Yes ☐ In which country is the head office of your group located? ³ _____ HO

No ☐

If your enterprise is part of an enterprise group: Please answer all further questions only for the enterprise for which you are responsible in [your country]. Exclude all subsidiaries or parent enterprises.

Figure 3.5: Question used to define *MNC* in the harmonised CIS 2008

1.1 In 2014, was your enterprise part of an enterprise group? (A group consists of two or more legally defined enterprises under common ownership. Each enterprise in the group can serve different markets, as with national or regional subsidiaries, or serve different product markets. The head office is also part of an enterprise group.) GP

Yes ☐ In which country is the head office of your group located? ³ _____ HO

No ☐

If your enterprise is part of an enterprise group: Please answer all further questions about your enterprise only for its own activities in [your country]. Exclude all subsidiaries or parent enterprises.

Figure 3.6: Question used to define *MNC* in the harmonised CIS 2014

We capture the number of external cooperation partners involved in the innovation progress by including *ext. coop* and the respective squared term. In total, we consider seven different cooperation partners based on the survey questions presented in Figures 3.7 and 3.8. In the CIS 2014, information about cooperation with clients and customers is split into the private and public sector. Both categories are matched into a single category to improve the comparability across survey waves.

6.2 During the three years 2006 to 2008, did your enterprise co-operate on any of your innovation activities with other enterprises or institutions? Innovation co-operation is active participation with other enterprises or non-commercial institutions on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active co-operation.

Yes ☐
 No ☐ (Please go to question 7.1) CO

6.3 Please indicate the type of innovation co-operation partner by location

(Tick all that apply)

Type of co-operation partner	[Your country]	Other Europe*	United States	China or India	All other countries
A. Other enterprises within your enterprise group	<input type="checkbox"/> Co11	<input type="checkbox"/> Co12	<input type="checkbox"/> Co13	<input type="checkbox"/> Co14	<input type="checkbox"/> Co15
B. Suppliers of equipment, materials, components, or software	<input type="checkbox"/> Co21	<input type="checkbox"/> Co22	<input type="checkbox"/> Co23	<input type="checkbox"/> Co24	<input type="checkbox"/> Co25
C. Clients or customers	<input type="checkbox"/> Co31	<input type="checkbox"/> Co32	<input type="checkbox"/> Co33	<input type="checkbox"/> Co34	<input type="checkbox"/> Co35
D. Competitors or other enterprises in your sector	<input type="checkbox"/> Co41	<input type="checkbox"/> Co42	<input type="checkbox"/> Co43	<input type="checkbox"/> Co44	<input type="checkbox"/> Co45
E. Consultants, commercial labs, or private R&D institutes	<input type="checkbox"/> Co51	<input type="checkbox"/> Co52	<input type="checkbox"/> Co53	<input type="checkbox"/> Co54	<input type="checkbox"/> Co55
F. Universities or other higher education institutions	<input type="checkbox"/> Co61	<input type="checkbox"/> Co62	<input type="checkbox"/> Co63	<input type="checkbox"/> Co64	<input type="checkbox"/> Co65
G. Government or public research institutes	<input type="checkbox"/> Co71	<input type="checkbox"/> Co72	<input type="checkbox"/> Co73	<input type="checkbox"/> Co74	<input type="checkbox"/> Co75

*: Include the following European Union (EU) countries, EFTA, or EU candidate countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.

Figure 3.7: Question used to define *ext. coop* in the harmonised CIS 2008

7.1 During the three years 2012 to 2014, did your enterprise co-operate on any of your innovation activities with other enterprises or organisations? Innovation co-operation is active participation with other enterprises or organisations on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active co-operation.

No ☐ (Go to section 8) CO
 Yes ☐ (Go to question 7.2)

7.2 Please indicate the type of innovation co-operation partner by location

(Tick all that apply)

Type of co-operation partner	[Your country]	Other Europe**	United States	China or India	All other countries
A. Other enterprises within your enterprise group	<input type="checkbox"/> Co11	<input type="checkbox"/> Co12	<input type="checkbox"/> Co13	<input type="checkbox"/> Co14	<input type="checkbox"/> Co15
B. Suppliers of equipment, materials, components, or software	<input type="checkbox"/> Co21	<input type="checkbox"/> Co22	<input type="checkbox"/> Co23	<input type="checkbox"/> Co24	<input type="checkbox"/> Co25
C. Clients or customers from the private sector	<input type="checkbox"/> Co311	<input type="checkbox"/> Co312	<input type="checkbox"/> Co313	<input type="checkbox"/> Co314	<input type="checkbox"/> Co315
D. Clients or customers from the public sector*	<input type="checkbox"/> Co321	<input type="checkbox"/> Co322	<input type="checkbox"/> Co323	<input type="checkbox"/> Co324	<input type="checkbox"/> Co325
E. Competitors or other enterprises in your sector	<input type="checkbox"/> Co41	<input type="checkbox"/> Co42	<input type="checkbox"/> Co43	<input type="checkbox"/> Co44	<input type="checkbox"/> Co45
F. Consultants or commercial labs	<input type="checkbox"/> Co51	<input type="checkbox"/> Co52	<input type="checkbox"/> Co53	<input type="checkbox"/> Co54	<input type="checkbox"/> Co55
G. Universities or other higher education institutes	<input type="checkbox"/> Co61	<input type="checkbox"/> Co62	<input type="checkbox"/> Co63	<input type="checkbox"/> Co64	<input type="checkbox"/> Co65
H. Government, public or private research institutes	<input type="checkbox"/> Co71	<input type="checkbox"/> Co72	<input type="checkbox"/> Co73	<input type="checkbox"/> Co74	<input type="checkbox"/> Co75

7.3 Which type of co-operation partner was the most valuable for your enterprise's innovation activities? (Give corresponding letter) _____ PMOS

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

** Include the following European Union (EU) and associated countries: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, FYR Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.

Figure 3.8: Question used to define *ext. coop* in the harmonised CIS 2014

We further proxy absorptive capacity with a dummy *know-how* to capture whether a firm has acquired existing knowledge from other enterprises or organisation. In addition, we capture whether a firm is active in R&D. The underlying survey questions are part of Figures 3.9 and 3.10.

5.1 During the three years 2006 to 2008, did your enterprise engage in the following innovation activities:

		Yes	No	
In-house R&D	Creative work undertaken within your enterprise to increase the stock of knowledge for developing new and improved products and processes (include software development in-house that meets this requirement)	<input type="checkbox"/>	<input type="checkbox"/>	<i>RRDIN</i>
	If yes, did your enterprise perform R&D during 2006 to 2008:			<i>RDENG</i>
	Continuously (your enterprise has permanent R&D staff in-house)	<input type="checkbox"/>		
	Occasionally (as needed only)		<input type="checkbox"/>	
External R&D	Same activities as above, but performed by other enterprises (including other enterprises or subsidiaries within your group) or by public or private research organisations and purchased by your enterprise	<input type="checkbox"/>	<input type="checkbox"/>	<i>RRDEX</i>
Acquisition of machinery, equipment and software	Acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved products and processes	<input type="checkbox"/>	<input type="checkbox"/>	<i>RMAC</i>
Acquisition of external knowledge	Purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other enterprises or organisations for the development of new or significantly improved products and processes	<input type="checkbox"/>	<input type="checkbox"/>	<i>ROEK</i>

Figure 3.9: Question used to define *know-how* (ROEK) and *R&D activity* (RRDIN) in the harmonised CIS 2008

5.1 During the three years 2012 to 2014, did your enterprise engage in the following innovation activities:

		Yes 1	No 0	
In-house R&D	Research and development activities undertaken by your enterprise to create new knowledge or to solve scientific or technical problems (include software development in-house that meets this requirement)	<input type="checkbox"/>	<input type="checkbox"/>	<i>RRDIN</i>
	If yes, did your enterprise perform R&D during the three years 2012 to 2014:			
	Continuously (your enterprise had permanent R&D staff in-house)	<input type="checkbox"/>		<i>RDENG</i>
	Occasionally (as needed only)		<input type="checkbox"/>	
External R&D	Your enterprise contracted-out R&D to other enterprises (include enterprises in your own group) or to public or private research organisations	<input type="checkbox"/>	<input type="checkbox"/>	<i>RRDEX</i>
Acquisition of machinery, equipment, software & buildings	Acquisition of advanced machinery, equipment, software and buildings to be used for new or significantly improved products or processes	<input type="checkbox"/>	<input type="checkbox"/>	<i>RMAC</i>
Acquisition of existing knowledge from other enterprises or organisations	Acquisition of existing know-how, copyrighted works, patented and non-patented inventions, etc. from other enterprises or organisations for the development of new or significantly improved products and processes	<input type="checkbox"/>	<input type="checkbox"/>	<i>ROEK</i>

Figure 3.10: Question used to define *know-how* (ROEK) and *R&D activity* (RRDIN) in the harmonised CIS 2014

Next, we add a dummy *subsidies* to indicate whether the firm has received any public support for its innovation, subsidies for which must have been received in the 3 years prior to the survey. Figures 3.11 and 3.12 present the respective questions used to create the variable. The dummy captures whether FUNLOC, FUNGMT, FUNEU or FUNRTD was selected.

5.3 During the three years 2006 to 2008, did your enterprise receive any public financial support for innovation activities from the following levels of government? Include financial support via tax credits or deductions, grants, subsidised loans, and loan guarantees. Exclude research and other innovation activities conducted entirely for the public sector under contract.

	Yes	No	
Local or regional authorities	<input type="checkbox"/>	<input type="checkbox"/>	FUNLOC
Central government (including central government agencies or ministries)	<input type="checkbox"/>	<input type="checkbox"/>	FUNGMT
The European Union (EU)	<input type="checkbox"/>	<input type="checkbox"/>	FUNEU
If yes, did your enterprise participate in the EU 6 th or 7 th Framework Programme for Research and Technical Development?	<input type="checkbox"/>	<input type="checkbox"/>	FUNRTD

Figure 3.11: Question used to define *subsidies* in the harmonised CIS 2008

6.1 During the three years 2012 to 2014, did your enterprise receive any public financial support for innovation activities from the following levels of government? Include financial support via tax credits or deductions, grants, subsidised loans, and loan guarantees. Exclude R&D and other innovation activities conducted entirely for the public sector* under contract.

	Yes	No	
	1	0	
Local or regional authorities	<input type="checkbox"/>	<input type="checkbox"/>	FUNLOC
Central government (including central government agencies or ministries)	<input type="checkbox"/>	<input type="checkbox"/>	FUNGMT
The European Union (EU)	<input type="checkbox"/>	<input type="checkbox"/>	FUNEU
If yes, did your enterprise participate in the EU 7 th Framework Programme for Research and Technical Development or in the Horizon 2020 Programme for Research and Innovation?	<input type="checkbox"/>	<input type="checkbox"/>	FUNRTD

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

Figure 3.12: Question used to define *subsidies* in the harmonised CIS 2014

In addition, we capture with *EPS (home)* the EPS in the domestic economy. To this end, we calculate the sector-based average of firms claiming to have adopted EIs in response to environmental regulation (excluding exporters). The respective survey questions are presented in Figures 3.13 and 3.14. In more detail, we use the variable ENREG in the CIS 2008 and ENEREG in the CIS 2014. The CIS 2014 asks respondents to note the degree of importance, while CIS 2008 restricts responses to 'yes' and 'no'. For the CIS 2014, we coded an answer as yes if the degree of importance is high or medium.

5.3 During the three years 2006 to 2008, did your enterprise receive any public financial support for innovation activities from the following levels of government? Include financial support via tax credits or deductions, grants, subsidised loans, and loan guarantees. Exclude research and other innovation activities conducted entirely for the public sector under contract.

	Yes	No	
Local or regional authorities	<input type="checkbox"/>	<input type="checkbox"/>	FUNLOC
Central government (including central government agencies or ministries)	<input type="checkbox"/>	<input type="checkbox"/>	FUNGMT
The European Union (EU)	<input type="checkbox"/>	<input type="checkbox"/>	FUNEU
If yes, did your enterprise participate in the EU 6 th or 7 th Framework Programme for Research and Technical Development?	<input type="checkbox"/>	<input type="checkbox"/>	FUNRTD

Figure 3.13: Question used to define *EPS (home)* in the harmonised CIS 2008

6.1 During the three years 2012 to 2014, did your enterprise receive any public financial support for innovation activities from the following levels of government? Include financial support via tax credits or deductions, grants, subsidised loans, and loan guarantees. Exclude R&D and other innovation activities conducted entirely for the public sector* under contract.

	Yes 1	No 0	
Local or regional authorities	<input type="checkbox"/>	<input type="checkbox"/>	FUNLOC
Central government (including central government agencies or ministries)	<input type="checkbox"/>	<input type="checkbox"/>	FUNGMT
The European Union (EU)	<input type="checkbox"/>	<input type="checkbox"/>	FUNEU
If yes, did your enterprise participate in the EU 7 th Framework Programme for Research and Technical Development or in the Horizon 2020 Programme for Research and Innovation?	<input type="checkbox"/>	<input type="checkbox"/>	FUNRTD

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

Figure 3.14: Question used to define *EPS (home)* in the harmonised CIS 2014

Finally, we control for the size of companies by including *(ln) turnover*. The respective survey questions are presented in Figures 3.15 and 3.16. We use the respective variables TURN2008 and TURN14, measuring the total turnover of the respective year in EUR.

11.1 What was your enterprise's total turnover for 2006 and 2008?⁶ Turnover is defined as the market sales of goods and services (Include all taxes except VAT⁷).

2006	2008
<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>
TURN06	TURN08

Figure 3.15: Question used to define *(ln) turnover* in the harmonised CIS 2008

14.1 What was your enterprise's total turnover for 2012 and 2014?⁸ Turnover is defined as the market sales of goods and services (Include all taxes except VAT⁹)

2012	2014
<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>
TURN12	TURN14

Figure 3.16: Question used to define *(ln) turnover* in the harmonised CIS 2014

Summary statistics split by CIS 2008 and CIS 2014

Tables 3.2, 3.3 and 3.4 include the summary statistics for the dependent and independent variables, including all observations as well as limited to the respective survey wave.

Table 3.2: Summary statistics, including CIS 2008 and CIS 2014

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
EI adoption	23,653	0.609	0.488	0	1
Nr. of EI adoption	23,653	2.518	2.680	0	8
Process-based EI adoption	23,653	0.584	0.493	0	1
Nr. of process-based EI adoption	23,653	1.736	1.816	0	5
Product-based EI adoption	23,653	0.403	0.491	0	1
Nr. of product-based EI adoption	23,653	0.782	1.087	0	3
Some exports	23,653	0.432	0.495	0	1
Exports dominate	23,653	0.32	0.465	0	1
Market EPS	23,653	1.186	0.192	0.486	1.589
Non-m. EPS	23,653	1.340	0.118	0.812	1.814
MNC	23,653	0.175	0.380	0	1
Ext. coop.	23,653	0.871	1.608	0	7
R&D	23,653	0.464	0.499	0	1
Know-how acquisition	23,653	0.198	0.399	0	1
Subsidies	23,653	0.284	0.451	0	1
Turnover in EUR	23,653	6.833e+07	6.547e+08	1,193	4.179e+10
(ln) turnover in EUR	23,653	15.44	2.031	7.085	24.46
EPS (home)	23,653	0.564	0.192	0	1

Table 3.3: Summary statistics, including CIS 2008

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
EI adoption	15,333	0.628	0.483	0	1
Nr. of EI adoption	15,333	2.722	2.755	0	8
Process-based EI adoption	15,333	0.604	0.489	0	1
Nr. of process-based EI adoption	15,333	1.861	1.852	0	5
Product-based EI adoption	15,333	0.432	0.495	0	1
Nr. of product-based EI adoption	15,333	0.860	1.127	0	3
Some exports	15,333	0.296	0.496	0	1
Exports dominate	15,333	0.265	0.441	0	1
Market EPS	15,333	1.287	0.147	0.805	1.589
Non-m. EPS	15,333	1.325	0.111	1.060	1.814
MNC	15,333	0.158	0.365	0	1
Ext. coop.	15,333	0.873	1.652	0	7
R&D	15,333	0.475	0.499	0	1
Know-how acquisition	15,333	0.205	0.404	0	1
Subsidies	15,333	0.248	0.432	0	1
Turnover in EUR	15,333	8.516e+07	7.894e+08	1,193	4.179e+10
(ln) turnover in EUR	15,333	15.51	2.113	7.085	24.46
EPS (home)	15,333	0.471	0.152	0	1

Table 3.4: Summary statistics, including CIS 2014

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
EI adoption	8,320	0.574	0.495	0	1
Nr. of EI adoption	8,320	2.143	2.493	0	8
Process-based EI adoption	8,320	0.548	0.498	0	1
Nr. of process-based EI adoption	8,320	1.505	1.724	0	5
Product-based EI adoption	8,320	0.349	0.477	0	1
Nr. of product-based EI adoption	8,320	0.638	0.995	0	3
Some exports	8,320	0.417	0.493	0	1
Exports dominate	8,320	0.414	0.493	0	1
Market EPS	8,320	1.000	0.106	0.486	1.266
Non-m. EPS	8,320	1.369	0.124	0.812	1.696
MNC	8,320	0.206	0.404	0	1
Ext. coop.	8,320	0.868	1.524	0	7
R&D	8,320	0.443	0.497	0	1
Know-how acquisition	8,320	0.186	0.389	0	1
Subsidies	8,320	0.351	0.477	0	1
Turnover in EUR	8,320	3.730e+07	2.624e+08	11,760	1.078e+10
(ln) turnover in EUR	8,320	15.31	1.862	9.372	23.10
EPS (home)	8,320	0.736	0.127	0	1

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Chapter 4

On the Drivers of Clean Production: Firms' Global Value Chain Positioning* †

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Abstract

Industries that occupy upstream positions in global value chains (GVCs) - being positioned closer to the raw product - produce proportionately more CO₂-intensive. However, firms are heterogeneous, even in narrowly defined industries. In this paper, I empirically investigate whether the relationship between upstreamness and CO₂ emissions, measured in absolute and relative terms, holds within industries at the firm level. Using granular data of Indian manufacturing firms and controlling for established drivers of clean production, I reveal that firms producing products closer to final consumption produce less CO₂-intensive. I corroborate the finding by using a 2-SLS instrumental variable approach. Interestingly, I find that exposure to importing countries with stringent environmental policies attenuates the link between upstreamness and dirty production. The latter finding suggests the imperative of technology upgrading for dirty upstream producers aiming to remain competitive in international markets.

JEL Classification Numbers: F14, F18, O13, Q56.

Keywords: Environment and trade; environment and development; CO₂ intensity; global value chains; sustainable development.

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Highlights

- In this paper, I empirically investigate the relation between firms' CO₂ emissions and GVC positions
- I find that within industries firms that occupy upstream GVC positions produce more CO₂-intensive
- Exposure to export markets with strong environmental regulation moderates (negatively) the relation between upstreamness and dirty production
- A firm's export status does not significantly moderate the relation between upstreamness and dirty production
- Accelerating the environmental abatement of firms in upstream GVC positions is key reaching global goals on CO₂ emissions

4.1 Introduction

Promoting the green transition of industries is a pressing challenge of our time and it is covered in the United Nations Sustainable Development Goals 9 and 12. Even in the light of energy efficiency gains over the last decades, economic growth strongly correlates with energy consumption and energy consumption itself strongly correlates with greenhouse gas (GHG) emissions (Costa-Campi et al., 2015). Global warming, a consequence of GHG emissions, represents a serious threat for future generations through increasingly volatile weather conditions, changed agricultural productivity, threatened biodiversity and elevated sea levels. Emerging and developing countries are especially vulnerable to the economic risks related to global warming. At the same time, with their economic rise, most of the global increase in GHG emissions originates from these countries (Copeland et al., 2022). Accordingly, beyond the urgency of a significant decoupling between economic growth and GHG emissions in industrialised countries, major successes in GHG emission reduction of developing and emerging countries are crucial if there is any hope of attaining the Paris Agreement’s target of limiting global warming to well below 1.5°Celsius.

This paper, contributes to the understanding of the determinants of firms’ clean production, measured as reductions of firms’ CO₂ emissions and CO₂ intensity, in developing countries. In so doing, I complement prior studies on the relationship between a firm’s global value chain (GVC) participation and its environmental performance - the focus being a firm’s GVC positioning, rather than foreign ownership, export, or import status (Batrakova and Davies, 2012; Brucal et al., 2019; Gutiérrez and Teshima, 2018). To this end, I empirically analyse data of firms based in India, the third largest global emitter of CO₂ and a country with historically high rates of emissions growth. A main contribution to the literature is whether Shapiro’s (2021) finding of a negative relationship between industries’ upstreamness and clean production can be confirmed at the firm level. Specifically, this means confirming whether firms located more upstream along the GVC - being positioned closer to the raw product than their peers producing a similar core product - demonstrate a worse environmental performance. Additionally, I investigate whether a firm’s exports and exposure to export markets characterised by stringent environmental policies, negatively moderates the relationship for upstreamness.

The negative relationship between industries’ upstreamness and clean production is monotonous and somewhat linear across industries and countries, at all stages of development (Shapiro, 2021). In line with this finding, Copeland et al. (2022) list as a stylised fact that upstream industries do indeed carry a heavier environmental footprint. However, firms are heterogeneous, even within narrowly defined industries (Melitz, 2003). Accordingly, relationships observed at the industry level cannot comment on firm level phenomena such as productivity, exports or product mix. These and other firm level idiosyncrasies, which potentially relate to the environmental performance of a firm, motivate this paper. There are strong intuitions why these firm level phenomena matter. Firstly, differences in the product mix are expected to connect both to a firm’s GVC positioning as well as the environmental impact of its production. A manufacturing firm that also sells mining products is likely to report worse CO₂ intensity than its peers because mining products require more energy, on average, during the production process. At the same time, mining products are more predominant in upstream GVC positions.

Second, productivity varies substantially between firms within an industry and productive firms are more likely to participate in global trade (Melitz, 2003). A firm’s trade participation can induce additional productivity gains, technology upgrading, and improvements in its environmental performance (Bustos, 2011; Cherniwchan et al., 2017; Copeland et al., 2022; Shapiro and Walker, 2018).

Gutiérrez and Teshima (2018) argue that developing countries, in particular, can benefit environmentally from trade-induced technology adoption because firms based in these countries are, on average, further removed from the technology frontier. I argue that a similar claim might hold for the relationship between upstreamness and cleaner production. If firms in upstream value chain positions are characterised by a higher distance to the technology frontier, they might benefit disproportionately from trade-related drivers of cleaner production. These benefits from trade could arise from learning-by-exporting, demand-pull, and regulation-push (Brunnermeier and Cohen, 2003; De Loecker, 2007; Horbach, 2008). Additionally, they are more pronounced for firms exposed to countries with higher degrees of environmental policy stringency (EPS) (Hanley and Semrau, 2022). The latter might link to a negative moderating role of EPS exposure on the relationship between upstreamness and dirty production. However, strong environmental regulation in import destinations can cause firms in developing countries to fully specialise in the production of (dirty) inputs not conforming to these standards (Acemoglu et al., 2014). Outsourcing of dirty production to countries with lax environmental regulation is in line with the pollution haven hypothesis, as outlined by Antweiler et al. (2001) and Eskeland and Harrison (2003).

Similar to Barrows and Ollivier’s (2021) recent contribution on the nexus between the GVC participation of firms and their environmental performance, I use the Prowess database. I denote clean production by firms’ CO₂ emissions and CO₂ emissions per unit of sales. Additionally, I follow Dardati and Saygili (2021), measuring firms’ CO₂ intensity by using CO₂ emissions per unit of value added. In this way, value added is calculated by subtracting spending on intermediates from the sales of each firm, which covers the value of a good acquired in prior stages of the GVC. Producing these intermediates is linked to indirect emissions along the GVC, emissions that are emitted during the production of the intermediates and transportation. Accordingly, using CO₂ per value added provides a measure for a firm’s environmental performance at a specific stage of the value chain.

Exploiting firm level information, the CO₂ emissions of a firm are calculated using data on the quantities of energy consumed, for each energy sources used. Such detailed firm level information is rare in the context of a developing country and makes it possible to regard differences in CO₂ emissions between different sources of energy, in a way that is not captured if energy costs are applied as a proxy for clean production (Barrows and Ollivier, 2018, 2021). To measure the GVC position of a firm, I apply the industry level GVC measure of Antràs et al. (2012) and Antràs and Chor (2018). Specifically, I follow the methodology of Herkenhoff et al. (2021), calculating the Indian industry-year-specific GVC positions by employing the WIOD available for the period from 2000 to 2014 (Timmer et al., 2015). I then combine the industry information with the product level information component of Prowess to calculate firm-specific GVC positions (Herkenhoff et al., 2021). Empirically, I apply an OLS regression,

controlling for established drivers of clean production. By including industry fixed effects, the empirically exploited variation in GVC positions originates from differences in the product mix of firms within an industry (Herkenhoff et al., 2021). In two alternative specifications, I include respective interaction terms - first, between a firm's upstreamness and exports, and second, between a firm's upstreamness and its exposure to markets characterised by a high EPS.

The main empirical finding confirms the stylised fact that firms occupying upstream GVC positions report higher CO₂ emissions from their production. The effect is statistically significant and economically meaningful. A change in the upstreamness measure by one unit, such as the equivalent of switching from the average GVC position of firms in the *textiles* industry to the *basic metals* industry, increases the estimated CO₂ emissions by 28.15%, CO₂ per unit of sales by 26.87% and CO₂ per unit of value added by 35.39%, respectively. A comparison of firms in very downstream positions, with firms in very upstream positions further illustrates the economically meaningful difference. The estimated CO₂ emissions increase by 63.23%, CO₂ per unit of sales by 60.0%, and CO₂ per unit of value added by even 82.21%. The latter corresponds to an increase from 0.76 kg to 1.39 kg CO₂ emissions per US dollar value added.

Beyond the main finding, I reveal that the relationship between upstreamness and dirty production decreases with exposure to strong environmental regulation. For firms in upstream positions exposed to strong environmental regulation in export markets, the relationship between upstreamness and dirty production even disappears completely. This finding links to the adoption of more efficient technologies by firms aiming to remain competitive in environmentally demanding export markets. Learning-by-exporting, regulation-push, and demand-pull help firms to adoption of these technologies and are especially relevant for dirtier producers in upstream positions, arguably more remote from the technology frontier. For downstream firms, environmental performance deteriorates with exposure to strong environmental regulation in export markets. The finding suggests that, on average, producers in downstream positions specialise in the production of dirty inputs, while producers in upstream positions demonstrate environmental gains from exposure to strong environmental regulation.

Interestingly, I do not find any moderating effect for exports on the relationship between upstreamness and clean production. The latter result suggests that firms located in more upstream positions do not benefit disproportionately from the trade-induced technique effect.

The key results on the relationship between upstreamness and clean production are robust to a variety of alternative specifications. These include the use of an alternative measure of environmental performance by firms, extending the number of covered firms in the estimation sample and the application of a 2-SLS instrumental variable approach. In the latter, I use advertising intensity (advertising expenditure to sales) among firms producing a similar core product. The relevance of the instrument is motivated by a higher incentive for advertising expenditure for firms in downstream positions, such as targeting final consumers. By excluding a firm's advertising spending and sales from the measure, the instrument is exogenously given to a firm and cannot be influenced by its managers or other stakeholders.

The underlying analysis takes place against a backdrop in which policy-makers, keen to foster the transition towards a green economy, are seeking to understand the determinants of clean production. I focus on India, a country that faces multiple challenges. Apart from striving

to deal with environmental degradation, India faces other challenges in its efforts to achieve sustainable development, including poverty elimination and energy security. The twin targets of transformation towards a green economy and social development are strongly intertwined. It is imperative to break the detrimental dynamic between economic development and GHG emissions to achieve the ultimate goal of sustainable development. The present study covers the period 2000 to 2014, during which India's share of global CO₂ emissions increased from 4.2% to 6.2%. Significantly, India's absolute CO₂ emissions more than doubled within this period, and in absolute terms, India being the third largest emitter in the world, even though its CO₂ emissions per capita are around 9.5 times less than the equivalent value for the United States (The World Bank, 2019).¹

One approach fostering a global green economic transition is to design trade policy in such a way that rewards clean production along the GVC and fosters a green economic transition. A CO₂ border adjustment tax could represent such an instrument, as it penalises dirtier producers along the GVC by targeting dirtier production with higher tariffs (Aichele and Felbermayr, 2015). However, Shapiro (2021) uncovers an environmental bias in trade policy, where industries in downstream positions can be confronted with higher tariffs vs. industries in upstream positions, even if their production is, on average, more environmentally efficient. Such a policy works against the desired outcome because it subsidises dirty production in upstream industries, thereby undermining the overall target of reducing global CO₂ emissions. My results lend strong support at the firm level to Shapiro's conclusion of trade-induced distortions, pointing to evidence of an environmental bias between relatively dirtier upstream, and cleaner downstream producers.

The remainder of this paper is structured as follows. The next section summarises studies connected to GVCs and the environment, based on which I formulate the testable hypotheses. Section 4.3 presents the database used in the analysis, the empirical methodology, a description of the variables used, and the descriptive statistics. Next, the empirical results, the instrumental variable approach, and robustness checks are presented. I conclude with a summary of the results and their implications.

4.2 Firm's GVC Positioning and Clean Production

Significant efficiency gains in GHG emissions per unit of output are needed in order to further decouple economic growth and GHG emissions. However, firms cannot fully appropriate the welfare gains of investments in cleaner production techniques, largely because of the double-externality characteristic of these investments (Jaffe et al., 2005; Rennings, 2000). Accordingly, firms invest less than the social optimum in GHG emissions reduction. Key determinants in correcting market failures, which boost environmental innovation and investment in cleaner production, are regulation-push, market-pull, technology push, and firm-specific factors (e.g.: Barbieri et al. (2016); Brunnermeier and Cohen (2003); Cainelli et al. (2012); del Río González (2009); De Marchi (2012); Ghisetti and Pontoni (2015); Ghisetti et al. (2015); Horbach (2008); Horbach et al. (2012); Horbach (2016); Kesidou and Demirel (2012); Rennings (2000)).

¹Downloaded on 20 December 2019

Building on Shapiro (2021), I focus on GVC positioning as a driver of clean production - a driver that has not been considered in prior firm level studies. Shapiro (2021) finds that upstream industries are characterised by reduced environmental efficiency. The reasons suggested for this pattern are multiple. First, firms in upstream industries take raw materials extracted from the ground and transform them. This is more energy-demanding than the production of downstream firms, which depend more on relatively cleaner inputs such as labour (Shapiro, 2021). Second, fossil energy inputs such as coal are disproportionately used by the heaviest industries, typically those occupying more upstream positions such as electricity generation, cement manufacturing, and steel blast furnaces (Shapiro, 2021).

There are also other mechanisms, which underpin the relationship between firms' upstreamness and dirty production, beyond those outlined by Shapiro (2021). Market-pull factors affect a firm's decision to invest in clean production (Horbach, 2008). Zhu et al. (2012) emphasise that downstream stakeholders - in particular - push firms to adopt environmental measures. For these stakeholders, downstream firms are relatively more visible than upstream firms; for instance, downstream products are a ubiquitous part of the daily routine of many consumers. If downstream stakeholders push for sustainable production, this urgency might diminish for less visible products, positioned further upstream the value chain.

Herkenhoff et al. (2021) theoretically and empirically analyse the relationship between the upstreamness and corporate social responsibility (CSR), which serves as another dimension of firms' sustainability in production. They reveal that firms in downstream positions spend comparatively more on CSR. A key reason is that CSR is characterised by incomplete contracts and CSR activities are observable, but not verifiable. As a result, firms have a higher incentive to invest in CSR once their suppliers invest in CSR. Herkenhoff et al. (2021) empirically confirm the prediction of amplifying CSR spending along the GVC, using the Indian Prowess database. It can be concluded from the Herkenhoff et al.'s study that a firm occupying a more downstream position might face a higher incentive to invest in environmentally friendly production techniques - an incentive underpinned by the prioritisation of environmental outcomes by suppliers along the GVC. These environmental-related expenditures share some similarities with CSR, because they are for buyers of intermediates observable, but not verifiable.

Contrary to the mechanisms described earlier, which help to trigger a negative relationship between upstreamness and clean production, a positive relationship can also be argued. Shapiro (2021) points to an environmental bias of trade policy due to lower tariffs for upstream industries, but higher CO₂ emissions per US dollar of output. Bustos (2011) introduces technology change into the Melitz (2003) model and finds that Argentinian firms that face relatively lower tariffs increase revenues by entering foreign markets and are therefore better able to absorb costs of technology upgrading. Kong et al. (2022) show that such technology upgrading is also linked to the improved environmental performance of firms. They find that China's trade liberalisation, following its World Trade Organization accession, significantly reduced the toxic emissions of firms. Combining the results by Shapiro (2021), Bustos (2011), and Kong et al. (2022), firms in upstream positions face lower tariffs and therefore have better access to foreign markets. This, in turn, encourages a firm to introduce technology upgrading and to improve its environmental performance. Nonetheless, viewing the evidence collectively and building on Shapiro (2021), I

would expect a negative relationship between upstreamness and clean production to prevail.

However, firms' exports might serve to moderate the negative relationship between upstreamness and clean production. Recent firm level studies have found that exports positively relate to firms' environmental performance (Batrakova and Davies, 2012; Forslid et al., 2018; Girma and Hanley, 2015; Hanley and Semrau, 2022; Richter and Schiersch, 2017). Gutiérrez and Teshima (2018) emphasise the positive impact of trade on technological choice can play a large role, especially for firms in developing countries, because such firms are generally further removed from the technology frontier. Arguably, firms in upstream positions produce in an environmentally less efficiently manner and are more remote from the technology frontier. In line with this, the expected relationship between upstreamness and dirty production might diminish with exports, because firms occupying upstream positions can benefit - in environmental terms - disproportionately from exports.

In general terms, studies investigating the effect of a firm's trade participation on its environmental outcomes in developing or emerging countries are scarce. An exception is Barrows and Ollivier (2021), who similarly use the Prowess database and focus on the direct CO₂ emissions of firms. The methodology used - calculating the CO₂ emissions embodied in the physical energy consumed - is also applied in Barrows and Ollivier (2018) and is novel in the context of an emerging country. However, the concept follows in the spirit of related studies by Richter and Schiersch (2017) and Forslid et al. (2018) who use German and Swedish data, respectively. Barrows and Ollivier (2021) reveal that foreign demand growth increases CO₂ emissions and improves CO₂ efficiency. Interestingly, they also find evidence for technological upgrading at the product level. In sum, foreign demand increases the level of total output, but simultaneous improvements in efficiency, on average, mitigate the scale effect, to the extent of about a half of this effect.

Apart from the expected effect for exports, I expect the magnitude of the relationship between GVC positioning and dirty production to diminish with increased exposure to EPS. Firms in upstream positions that face tough competition in international markets have a disproportionate need to adopt new technologies, in order to improve efficiency and to remain competitive in environmentally strongly regulated countries. In addition, Hanley and Semrau (2022) reveal that firms exposed to strong environmental regulation in import destinations demonstrate higher environmental innovation adoption rates. On average, consumers in countries with stringent environmental regulations have strong preferences for sustainable production and firms are more likely to be equipped with state-of-the-art technologies and skilled labour. Hanley and Semrau (2022) interpret this finding as a mixture of export-induced learning-by-exporting, demand-pull, and regulation-push transmitted through the value chain and augmented by high sustainability standards in import destinations (Brunnermeier and Cohen, 2003; De Loecker, 2007; Horbach, 2008; Newman et al., 2018). However, Acemoglu et al. (2014) emphasise that strong environmental regulation in import destinations may induce specialisation in the production of CO₂-intensive inputs by firms in developing countries, where the latter face relatively lax domestic EPS. In line with this, the pollution haven hypothesis predicts a shift of dirty industries to developing and emerging countries with less rigorous EPS (Antweiler et al., 2001; Eskeland and Harrison, 2003). The latter can lead to worse environmental performance of these

firms. However, it might be the case that these firms still produce in a more environmentally friendly way than their non-exporting domestic peers. Summarising the literature review how GVC participation relate to the environmental performance of firms, I empirically investigate the following hypotheses:

H1: *A firm's CO₂ emissions increases with upstreamness.*

H2: *A firm's CO₂ intensity increases with upstreamness.*

H3: *Exports negatively moderate the link between upstreamness and dirty production.*

H4: *Exposure to stringent environmental policy in export markets negatively moderates the link between upstreamness and dirty production.*

The next section presents the methodology, starting with a description of the data used.

4.3 Methodology

4.3.1 Data Description

I use the firm level Prowess database, merged with the WIOD to test the four hypotheses derived in the previous section. Comprising data on the financial performances of Indian firms, the Prowess data is provided by the Centre for Monitoring the Indian Economy.² Designed for academia (and other users), the data primary source information from income statements and balance sheets. Total production in Prowess covers more than 80% of India's GDP (Bos and Vannoorenberghe, 2018).

The empirical set-up spans the period between 2000 and 2014. Prowess data is also available before and after 2014. However, I apply the methodology of Herkenhoff et al. (2021), creating a measure of a firm's GVC position using the WIOD (Timmer et al., 2015).³ Unfortunately, the latter database is only available for the aforementioned period. Antràs et al. (2012) describe how World Input-Output Tables can be used to calculate a country-industry specific continuous measure of upstreamness. The approach by Herkenhoff et al. (2021) links the industry-specific GVC measure with the product level data of the Prowess database, the latter including information on the capacity, production, and sales, disclosed by firms. Such product level information is rare in the context of an emerging country, going back to the Indian 1956 Companies Act, which mandated to disclose such information in the annual report (Goldberg et al., 2010b).

Apart from such essential and not often accessible information at the product level, the coverage of energy consumption is unusual in the context of an emerging country. Firms report on their physical energy consumption, such as quantities of natural gas, electricity, coal, diesel or agricultural by-products consumed. The data availability goes back to a 1988 amendment in the Indian Companies Act, which forces firms to report on energy consumption by energy type. This level of detail makes it possible to calculate the heat content of energy consumption measured in MMBTU. The respective MMBTU of an energy source can be reformulated in

²The data were downloaded from <https://prowessdx.cmie.com/> on the 26th of November 2019. I downloaded the data in US dollars and deflated all monetary variables using the World KLEMS data. The KLEMS data were downloaded from <http://www.worldklems.net/data.htm>, using the sheet *GO_P*, which takes 2010 prices as the reference price. Last download on 21 September 2018.

³I also employ the WIOD Release 2016, including Input-Output Tables for 28 European countries and 15 other major economies (Timmer et al., 2015), downloaded from <http://www.wiod.org/home>

terms of its CO₂ content (Barrows and Ollivier, 2018, 2021).

Given its unique data coverage, the Prowess database is widely used in the economics literature, including international economics (e.g., Barrows and Ollivier (2018, 2021); De Loecker et al. (2016); Goldberg et al. (2010a,b)).

Similar to other studies analysing the determinants of a firm’s clean production, I limit the sample to the manufacturing base (Barrows and Ollivier, 2018, 2021; Richter and Schiersch, 2017). The manufacturing base is of particular interest in the context of GVCs and clean production because manufacturing products are comparatively high in CO₂ emissions, compared to service products. Additionally, manufacturing products are more frequently traded (Copeland et al., 2022). The next section presents the empirical strategy used in the analysis.

4.3.2 Empirical Analysis

Equations 4.1 and 4.2 illustrate the two main OLS estimations, with *CO₂ emissions* and *CO₂ intensity* used as dependent variables, respectively.

$$\ln(CO_2\ emissions_{ft}) = \alpha_0 + \beta_1 Upstreamness_{ft} + \beta_2 X_{ft} + \gamma_t + \delta_f + \epsilon_f + \zeta_f, \quad (4.1)$$

$$\ln(CO_2\ intensity_{ft}) = \alpha_0 + \beta_1 Upstreamness_{ft} + \beta_2 X_{ft} + \gamma_t + \delta_f + \epsilon_f + \zeta_f, \quad (4.2)$$

$CO_2\ emissions_{ft}$ is the natural logarithm of a firm’s f CO₂ emissions in kilotonnes (kt) in year t derived from its energy consumption during production. $CO_2\ intensity_{ft}$ is the natural logarithm of a firm’s CO₂ emissions in kt over its sales and value added in US dollars, respectively. The construction of the dependent variables is presented more comprehensively in Section 4.3.2.1.

$Upstreamness_{ft}$ is the main independent variable of interest. The value increases with the upstreamness of a firm f in year t . The measure varies over time with changes in a firm’s product mix. This is described in more detail in Section 4.3.2.2.

X_f captures different idiosyncrasies of the firm, potential co-determinants of the decision to apply a clean production technology. These drivers can be grouped into regulation-push, market-pull, technology-push, and firm-specific factors.⁴

EPS measures the exposure of a firm to foreign markets characterised by strong environmental regulation. On one hand, EPS exposure might connect to the transmission of regulation-push, demand-pull, and learning-by-exporting mechanisms through the value chain (Hanley and Semrau, 2022). On the other hand, domestic firms confronting weaker EPS can specialise in the production of dirty products (Acemoglu et al., 2014). The construction of EPS is presented in more detail in Section 4.3.2.3.

Firms that are active in dirtier industries are more likely to trade their outputs (Copeland et al., 2022). However, firm level studies reveal that exporters demonstrate higher energy and emission intensities (Barrows and Ollivier, 2021; Batrakova and Davies, 2012; Forslid et al.,

⁴For a literature review on the drivers of environmental innovation check Barbieri et al. (2016) and del Río González (2009).

2018; Richter and Schiersch, 2017). A dummy of a firm’s *export status* is added to capture the direct participation by a firm in GVCs. *Foreign ownership* captures another domain of GVC participation. Brucal et al. (2019) find that Indonesian firms that are acquired by foreign investors report higher CO₂ emissions but decreased CO₂ intensity than their non-acquired peers. As main reasons for the pattern, the authors highlight technology adoption through knowledge flows associated with foreign ownership. Additionally, they point to superior management practices of foreign-owned firms compared to purely domestic firms. Analogously, a multi-country analysis by Kannen et al. (2021) demonstrate empirically that foreign ownership relates to a higher adoption likelihood for green management practices. These practices, in turn, relate to improved environmental performance.

R&D captures a firm’s absorptive capacity and technology adoption. Ghisetti et al. (2015) discuss how a firm’s R&D links to higher environmental innovation adoption rates, improving the overall environmental performance of the firm. *(ln) productivity* measures a firm’s total factor productivity following the method by Akerberg et al. (2015). This approach makes it possible to deal with the functional dependence problems that may arise in the approaches used by Olley and Pakes (1996) and Levinsohn and Petrin (2003).⁵ Intuitively, a more productive firm is more likely to use state-of-the-art technologies, also associated with an improved environmental performance (Copeland et al., 2022; Shapiro and Walker, 2018).

In line with the importance of the product mix for a firm’s environmental performance, three dummies capture the production of non-manufacturing products: dummies for producing agricultural, mining, and service products. I also include a dummy that denotes firms which concentrate exclusively on the production of manufacturing products. The dummies are created based on the product level information component of Prowess. On average, service products require higher levels of labour inputs than manufacturing products. Since labour is a relatively clean input, it is important to control for this aspect. Conversely, agricultural and mining products might require higher energy inputs to extract the raw product. The latter is expected to be, on average, dirtier and more strongly associated with upstream positions (Shapiro, 2021).

A dummy for state ownership captures a possibly lower incentive for state-owned firms to invest in clean production; for example, due to reduced exposure to competition. The variable *(ln) assets* controls for size effects. Larger firms simply require more energy and have more possibilities to exploit scale effects. The latter improves the attractiveness of investment in CO₂ efficient techniques, since fixed costs can be more widely spread among a greater number of units produced (Forslid et al., 2018). Next, the *(ln) age* of a firm covers the aspect that young firms might be more innovative compared to relatively older firms.

γ_t covers year fixed effects and δ_f industry fixed effects of a firm’s core product. The variable ϵ_f is a spatial dummy for the state a firm is based, capturing differences such as in environmental regulation between Indian states. Lastly, ζ_f denotes the standard errors clustered at the firm level.⁶

⁵I applied the Stata command developed by Manjón et al. (2016). To derive a firm’s productivity, the firm’s value added is used as a dependent variable. In addition, standard errors are robust, a firm’s assets are used as state the variable, the wage bill is used as the free variable, and costs on intermediates is used as the proxy.

⁶I decided against the inclusion of firm fixed effects because of the limited within variation of *upstreamness*. Accordingly, the independent variable has only limited power to explain within firm variation in CO₂ emissions over time.

Section 4.4.2 presents an instrumental variable approach to regard for unobservable factors affecting both clean production and the GVC position of a firm. The instrumental variable for the GVC position of a firm considers advertising expenditure (advertising divided by sales) of the five-digit core product a firm produces. The respective measure excludes own advertising expenditure and sales. Next, Section 4.4.3 includes alternative specifications to shed light on Hypotheses 3 and 4. In these specifications, the upstreamness measure is multiplied by exports and exposure to the EPS of the firm’s foreign market, respectively. The interaction terms measure how the export status and EPS in export destinations moderate the relationship between upstreamness and dirty production. Lastly, Section 4.4.4 covers alternative robustness checks.

4.3.2.1 Measuring a Firm’s Clean Production

A firm’s annual CO₂ emissions in absolute and relative terms are used to proxy its clean production. I follow the methodology of Barrows and Ollivier (2018, 2021) to calculate firms’ direct CO₂ emissions emitted during production in kt. Also using the Prowess database, Barrows and Ollivier (2018, 2021) use conversion factors provided by the US EPA 2012 Climate Registry Default Emission Factors to transform energy consumption by energy type into CO₂ emissions. Since end-of-pipe carbon capture is not widely used by Indian firms, the CO₂ measure appropriately captures a firm’s direct CO₂ emissions (Barrows and Ollivier, 2021).⁷ The focus on direct energy inputs, excluding emissions embodied in intermediates or transportation, exclusively targets the production process within a firm.

I use two different approaches to measure CO₂ intensity. First, CO₂ emissions are divided by a firm’s annual sales in US dollars, corrected for changes in the stock (CO_2/SA). Dardati and Saygili (2021) claim that CO₂ emissions per unit of sales neglects firm-specific heterogeneity, such as the decision of exporters to outsource the production of intermediates. The production of intermediates embodies indirect CO₂ emissions. Dividing a firm’s CO₂ emissions by value added corrects for this shortcoming and serves as a direct measure of a firm’s CO₂ intensity in production (CO_2/VA). I derive a firm’s value added by excluding its spending on intermediates from sales.

Furthermore, I exclude observations with the lowest and highest centiles of the annual distribution for the three main outcomes - namely CO₂ emissions, CO₂ emissions per unit of sales, and CO₂ per unit of value added. The latter truncation is comparable to that applied by Barrows and Ollivier (2021). The final sample comprises 17,542 firm-year observations, offering relatively extensive coverage of firms in a country characterised by high and rising CO₂ emissions. However, not all firms report the necessary level of detail on energy consumption. In a robustness check, I significantly extend the sample by focusing on energy costs to measure the environmental performance of firms. In the next section, I introduce the main independent variable of interest: a firm’s GVC positioning.

⁷I updated the replication files, generously supplied by Barrows and Ollivier (2021), for the purposes of the present study. See Barrows and Ollivier (2018, 2021) and Section 4.6.1 of the Appendix for a detailed discussion on data construction and the quality of the derived firm level CO₂ emissions.

4.3.2.2 Measuring a Firm's GVC Positioning

Newman et al. (2018) state that the GVC position of a firm might affect CSR investments and empirically capture GVC positions, with the inclusion of industry fixed effects. This approach assumes that a firm's GVC position is a time-invariant variable. However, the GVC position of a firm might change over time, such as due to management decisions on the product mix. Herkenhoff et al. (2021) capture such changes in their firm-specific GVC measure. Their approach builds on the seminal contribution by Antràs et al. (2012) who employ World Input-Output Tables to measure the GVC positions of industries. The industry measure equals to one if an industry sells its products exclusively to end consumers. The value rises to above one if a share is sold as intermediates and increases with distance to final consumption. For example, the value of the measure increases if an industry sells more intermediates to an industry that itself mainly sells to intermediaries.

I follow Herkenhoff et al. (2021) by employing the WIOD to calculate Indian industry-specific GVC positions for the period in question. These GVC positions are merged with the product level Prowess database. Next, the respective GVC positions are weighted by a firm's relative sales in any given year.⁸ Equation 4.3 summarizes how a firm's value chain position in a specific year is derived:

$$U_{ft} = \sum_{v=1}^V \frac{sales_{fvt}}{sales_{ft}} U^{vt}, \quad (4.3)$$

U_{ft} is a firm's f upstreamness at time t selling products from V different industries. A firm's GVC position considers the respective product mix by weighting a product's GVC position U^{vt} with a firm's share of total sales in year t . Firms' GVC positions differ between firms within an industry for two main reasons. First, firms differ in their product mix; for example manufacturing firms also sell service products. Second, firms produce similar products, but the relative sale share differs.

Generally, I expect a positive relationship between upstreamness and the dependent variables of a firm's dirty production. Also, in line with Herkenhoff et al. (2021), I only regard tradable industries in the calculation of the firm-specific GVC positions, which for instance means excluding the following industries: (i) *human health and social work activities*, (ii) *postal and courier activities* or (iii) *education*. The next section introduces the measurement of exposure towards EPS in export markets.

4.3.2.3 Measuring Exposure to Environmental Policy Stringency in Export Markets

EPS measures a firm's export exposure towards environmentally demanding markets. The creation of the index follows Hanley and Semrau (2022) and exploits the OECD EPS Index (Botta and Koźluk, 2014). The WIOD is used to measure whether exports disproportionately

⁸Linking product level information with industry-specific GVC information is in line with Chor et al. (2021) who exploit Chinese data to analyse a firm's performance along the global production line. To this end, they weight the GVC positions of a firm's product mix with a product's export and import share.

target environmentally stringent markets. I focus on market-related EPS because it - relatively strongly - affects competition and environmental demands (Hanley and Semrau, 2022).

In addition to Hanley and Semrau (2022), and similar to the measure of upstreamness, I weight the industry-specific values with a firm's annual sales in a specific industry. Equation 4.4 summarises the proxy on EPS in export markets:

$$EPS_{fzt} = \sum_{z=1}^Z \frac{sales_{fzt}}{sales_{ft}} \frac{\sum_{k=1}^n \frac{EPS_{kt}}{\sum_{k=1}^n EPS_{kt}} exports_{zkt}}{\frac{\sum_{k=1}^n exports_{zkt}}{n}} \quad (4.4)$$

EPS_{jzt} is the market-related environmental policy exposure of firm f , producing in industry z at time t . The first term measures the respective share of the firm's f sales in industry z at time t . The shares of a firm sum up to one. The second term captures the EPS exposure of industry z at time t , while regarding the respective stringency of an export destination country k . In line with this, EPS_{kt} is the market-related EPS in country k at time t and $exports_{zkt}$ measures the total exports of sector z to country k at time t . n is simply the number of countries covered in the OECD EPS index in a respective year.

Any score above one indicates that exports are generally targeted towards countries with an EPS score above the average, for each year. Accordingly, I expect a negative coefficient of the interaction between upstreamness and EPS , pointing to a negative moderating role in the relationship between upstreamness and dirty production. The next section presents some descriptive statistics, providing insights into the variables of interest.

4.3.3 Descriptive Statistics

Table 4.1 provides the summary statistics of the dependent and independent variables used in the analysis. To allow for a more straightforward interpretation of the extent to which a firm produces clean outputs, the independent variables are also stated without taking the natural logarithm. The summary statistics cover only those observations used in the empirical analysis.

Among the 17,542 year-firm observations, comprising 3,155 firms, firms emit an average of 92.96 kt CO₂ per year. With a value of 1,261, the standard deviation is significantly higher than the mean, indicating some large emitters. The latter pattern is reasonable because India is home to some very energy-demanding companies, such as producers of aluminium, forgings, paper or cement.

Focusing on the descriptive statistics on the CO₂ intensity, reveals that for one US dollar of sales, 1.59 kg CO₂ is emitted. The median of 0.54 kg is significantly lower, which again points to the role of some dirty producers. The average level of upstreamness is 2.18, with values being between 1.42 and 3.50. A total of 41.8% of firms state that they sell products to foreign markets. In terms of exposure to environmental policy stringency, the average value is below one, at a level of 0.96. A value below one reveals that firms, on average, sell to markets with less stringent environmental policy regulations compared to the average level of stringency covered in the OCED EPS index by Botta and Koźluk (2014).

In terms of ownership, 7.2% of the observations are foreign-owned, but only 0.19% are state-

Table 4.1: Summary statistic of covered variables

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
CO2 emissions (kt)	17,542	92.96	1,261	0.00228	84,296
(ln) CO2 emissions (kt)	17,542	1.836	2.060	-6.082	11.34
CO2 (kt)/SA (USD)	17,542	1.593	4.061	0.00755	149.1
(ln) CO2 (kt)/SA (USD)	17,542	-0.634	1.489	-4.886	5.005
Value added (USD)	17,542	36.34	411.4	0.00450	41,441
(ln) CO2 (kt)/VA (USD)	17,542	-0.0404	1.542	-4.505	5.347
Upstreamness	17,542	2.182	0.611	1.415	3.496
Export status	17,542	0.418	0.493	0	1
EPS	17,542	0.964	0.103	0.660	1.512
Foreign ownership	17,542	0.0719	0.258	0	1
SOE	17,542	0.00194	0.0440	0	1
Age in years	17,542	25.40	20.38	1	118
(ln) age	17,542	2.964	0.757	0	4.771
R&D dummy	17,542	0.168	0.374	0	1
Assets in million USD	17,542	61.28	443.9	0.0400	29,128
(ln) assets	17,542	2.372	1.599	-3.218	10.28
(ln) productivity	17,542	2.504	1.309	-2.924	10.33
Exclusive manufacturing	17,542	0.654	0.476	0	1
Agricultural products	17,542	0.0966	0.295	0	1
Mining products	17,542	0.0156	0.124	0	1
Service products	17,542	0.256	0.437	0	1
Number of products	16,186	3.572	2.976	1	78
Number of GVC industries	16,186	1.643	0.824	1	9
Number of firms	3,155				

owned. 16.8% of the observations show some R&D expenditure. Among observations for which product level information is available, firms span on average 1.64 industries in different GVC positions and produce on average 3.57 different products. The latter links to the importance of considering the product mix in the empirical analysis. Overall, 25.6% sell service products other than just their core manufacturing product; 1.56% of the observations sell mining products and 9.7% sell agricultural products that are both on average related to higher emissions and higher scores in the GVC upstreamness measure. 65.4% produce exclusively manufacturing products.

Figure 4.1 illustrates the development of CO₂ emissions over time, including the respective intensity measures. In addition, the median is illustrated to consider firms with very high CO₂ emissions of some firms.

A strongly increasing trend of CO₂ emissions over time is observable. The pattern is valid for the average and the median CO₂ emissions in a respective year. Focusing on average CO₂ emissions per unit of sales reveals a constant trend of average CO₂ intensity, but the median reveals a negative slope. A similar pattern is observable for CO₂ emissions per unit of value added. The latter two patterns indicate that a majority of firms show efficiency gains over time. However, these efficiency gains are offset by some observations with high CO₂ intensities, turning the slope of the averages towards zero.⁹

Table 4.2 provides insights into the CO₂ emissions and intensities of specific sectors and the respective GVC positions. The table is ordered by decreasing upstreamness.

The *coke & refined petroleum products* industry shows the highest average CO₂ emissions with 624.97 kt. The industry is in the second most upstream GVC position. However, the median is only 0.54 kt and the dataset only covers 93 observations. In terms of median emissions, the *paper* industry shows the dirtiest production, with CO₂ emissions of 4.62 kt. Interestingly, the *paper* industry is also the industry with the highest means and medians of both CO₂ intensity measures.

⁹Notably, the year 2005 marks an outlier for the average emissions but not for the average intensities. The pattern is driven by some large emitters in the basic metal industry. For these firms, unfortunately, information on all included variables are only available for the year 2005. In the empirical set-up, controls for such particularities by including year and industry fixed effects.

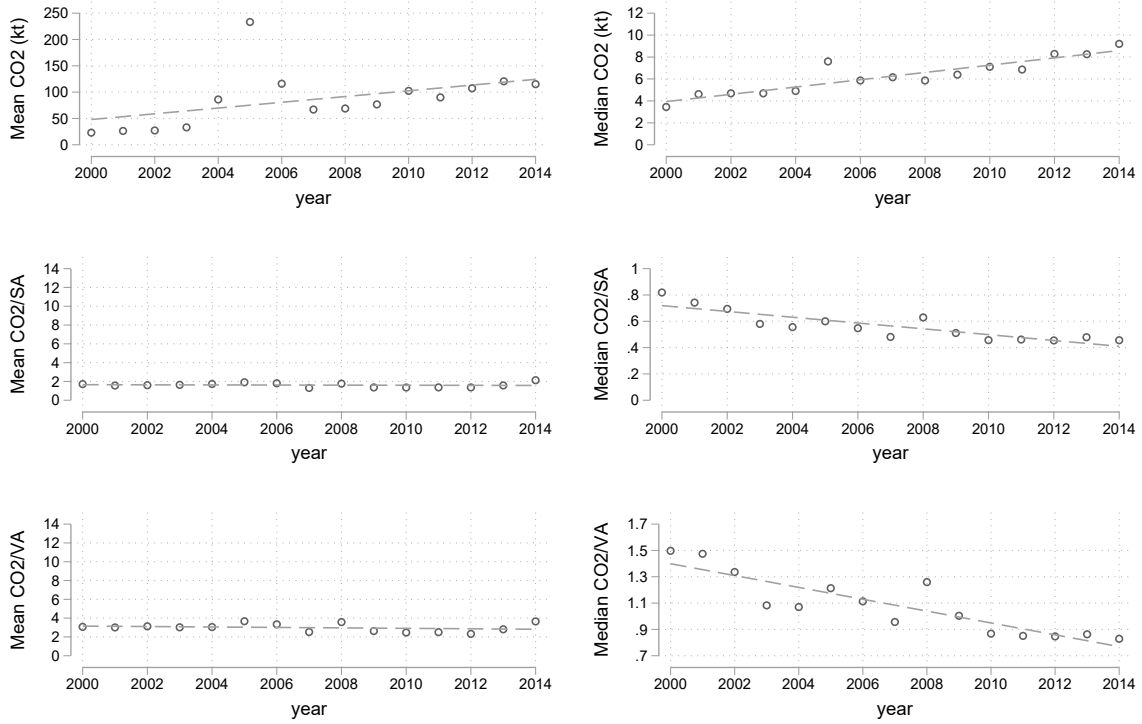


Figure 4.1: Development of CO₂ emissions over time

The top five most upstream industries have an average median of 12.68 kt, compared to a median of only 3.31 kt among the five most downstream industries. A similar pattern is observable for the mean (286.52.97 kt vs. 43.40 kt). The bias in environmental performance between downstream and upstream industries is also observable in the intensity measures. In terms of CO₂ emissions per US dollar of value added, the top five upstreamness industries emit 4.34 kg, on average, and the top five most downstream industries only emit an average of 1.37 kg.

All in all, the above findings show a upstreamness bias towards dirtier production. Notably, the *food* and *beverage* industries also show quite high levels of emissions, with a median of 5.96 kt of the *beverage* industry and 5.59 kt of the *food* industry, respectively. However, both values are still below the average median of the top five upstream industries described above. The next section presents the empirical results.

4.4 Results

The section starts by presenting the results of the main specifications.

4.4.1 A Firm's GVC Positioning and Clean Production

The first three columns of Table 4.3 include no industry fixed effects, linking the results closely to the study at the aggregated level by Shapiro (2021). The last three columns include industry fixed effects and limit the exploited variation of upstreamness to differences in the

Table 4.2: Industry statistic about CO₂ emissions and upstreamness

Industry	CO ₂ average	CO ₂ median	CO ₂ /SA average	CO ₂ /SA median	CO ₂ /VA average	CO ₂ /VA median	Upstr.	Obs.
Chemicals	52.76	6.33	1.09	0.47	2.07	0.98	3.19	2,500
Coke & refined petroleum products	624.97	0.54	0.57	0.12	1.68	0.36	2.75	93
Basic metals	305.77	11.97	1.89	0.60	3.73	1.31	2.67	2,545
Paper	116.43	29.08	4.62	4.00	9.34	7.71	2.62	977
Other non-metallic mineral	332.66	15.48	3.66	1.57	4.90	2.24	2.34	720
Rubber & plastics products	32.40	2.97	0.68	0.33	1.36	0.73	2.30	1,112
Fabricated metal products	15.24	4.88	0.66	0.41	1.44	0.81	2.28	646
Wood	4.46	1.15	1.92	0.91	3.79	1.61	2.17	23
Printing & reproduction of recorded media	0.06	0.06	0.09	0.09	0.09	0.09	2.12	1
Computer electronic & optical products	1.40	0.82	0.31	0.11	0.53	0.18	2.11	171
Electrical equipment	6.30	0.80	0.27	0.09	0.60	0.17	2.00	292
Machinery & equipment	11.41	0.74	0.66	0.12	1.05	0.20	1.95	538
Other manufacturing	49.24	0.90	0.94	0.10	1.41	0.23	1.93	72
Other transport equipment	20.72	1.67	0.15	0.06	0.30	0.17	1.82	46
Motor vehicles	8.50	4.16	0.28	0.17	0.51	0.33	1.78	379
Textiles	22.92	7.72	1.57	1.01	2.97	1.80	1.68	3,061
Leather	2.35	1.76	0.62	0.33	1.69	0.48	1.65	28
Wearing apparel	2.73	1.03	0.32	0.09	0.40	0.21	1.65	82
Beverages	41.79	5.96	0.89	0.29	1.48	0.39	1.60	236
Tobacco	94.17	1.05	0.09	0.04	0.12	0.04	1.59	18
Food	45.24	5.59	1.89	0.70	3.54	1.15	1.57	2,713
Pharmaceuticals	33.07	2.91	0.88	0.18	1.31	0.29	1.57	1,289

product mix of firms producing in the same main industry. Columns (1) and (4) focus on the determinants of firms' absolute CO₂ emissions, while the remaining columns focus on firms' CO₂ intensities.

Table 4.3: OLS estimation: Upstreamness and clean production

VARIABLES	(1) CO ₂	(2) CO ₂ /SA	(3) CO ₂ /VA	(4) CO ₂	(5) CO ₂ /SA	(6) CO ₂ /VA
Upstreamness	0.334*** (0.055)	0.289*** (0.053)	0.445*** (0.055)	0.248** (0.104)	0.238** (0.108)	0.303*** (0.107)
EPS	0.062 (0.273)	0.135 (0.269)	0.039 (0.270)	-0.052 (0.238)	0.115 (0.233)	0.022 (0.228)
Export status	-0.462*** (0.060)	-0.615*** (0.059)	-0.581*** (0.058)	-0.242*** (0.055)	-0.427*** (0.054)	-0.368*** (0.054)
Foreign ownership	-0.423*** (0.118)	-0.455*** (0.120)	-0.662*** (0.122)	-0.284*** (0.109)	-0.337*** (0.110)	-0.514*** (0.112)
R&D dummy	-0.201*** (0.075)	-0.320*** (0.078)	-0.448*** (0.080)	-0.009 (0.070)	-0.171** (0.070)	-0.254*** (0.072)
SOE	1.544*** (0.552)	1.332** (0.578)	1.353*** (0.477)	1.372*** (0.465)	1.195** (0.471)	1.191*** (0.366)
(ln) productivity	0.083*** (0.022)	-0.179*** (0.021)	-0.331*** (0.021)	0.037* (0.021)	-0.208*** (0.020)	-0.384*** (0.020)
(ln) assets	0.998*** (0.021)	0.077*** (0.020)	0.124*** (0.020)	0.947*** (0.019)	0.037** (0.018)	0.074*** (0.019)
(ln) age	0.290*** (0.038)	0.112*** (0.037)	0.038 (0.037)	0.200*** (0.034)	0.036 (0.033)	-0.047 (0.033)
Agricultural products	0.720*** (0.115)	0.565*** (0.119)	0.763*** (0.120)	0.349*** (0.105)	0.216** (0.109)	0.428*** (0.111)
Mining products	0.880*** (0.199)	1.104*** (0.197)	0.926*** (0.196)	0.648*** (0.192)	0.873*** (0.198)	0.693*** (0.190)
Service products	-0.034 (0.114)	-0.203* (0.119)	-0.128 (0.119)	0.030 (0.106)	-0.126 (0.109)	-0.058 (0.109)
Exclusive manufacturing	0.172 (0.123)	0.154 (0.128)	0.160 (0.127)	0.093 (0.113)	0.096 (0.116)	0.091 (0.116)
Observations	17,542	17,542	17,542	17,541	17,541	17,541
R-squared	0.535	0.172	0.202	0.627	0.341	0.365
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	No	No	No	Yes	Yes	Yes
State dummy	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses (clustered at the firm level)

*** p<0.01, ** p<0.05, * p<0.1

Upstreamness is positively significant in all six specifications. Interestingly, the coefficients are higher and standard deviations are lower for the specifications without industry fixed effects. However, the coefficients remain significant once industry fixed effects are added. This strongly backs the results and policy conclusions of Shapiro (2021) in the context of an applied micro-level approach, controlling for several firm characteristics. Accordingly, firms producing in upstream industries show a dirtier production, indicated by higher CO₂ emissions and CO₂ emission intensities. Notably, comparing the results of CO₂ intensity per unit of sales with CO₂

intensity per unit of value added reveals stronger results for using value added as a measure of CO₂ intensity. A change in the upstreamness measure by one unit, such as switching from the average GVC position of firms in the *textiles* industry to the *basic metals* industry - increases the estimated CO₂ emissions by 28.15%, CO₂ per unit of sales by 26.87%, and CO₂ per unit of value added by 35.39%.¹⁰

Figure 4.4 illustrates the estimated level of absolute CO₂ emissions and CO₂ intensities for different GVC positions, once all other variables are held constant at their means. The specifications depicted are Columns (4), (5), and (6) of Table 4.3.

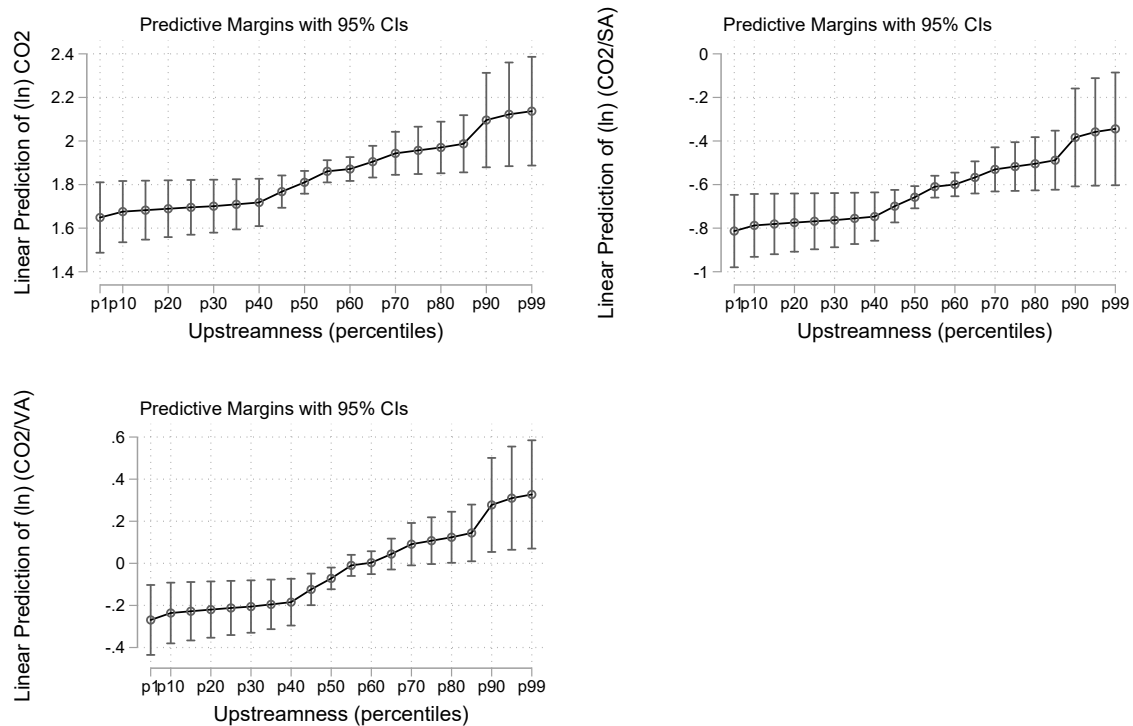


Figure 4.2: Estimated relationship between GVC positioning and CO₂ emissions and CO₂ intensities, respectively (Columns (4), (5), and (6) of Table 4.3)

At the first percentile, the estimated level of CO₂ emission is $\ln(1.65)$ at a upstreamness of 1.43, while the effect at the 99th percentile is $\ln(2.14)$ at a upstreamness of 3.39. Taking the exponential function to obtain the value in kt leads to a magnitude of 5.21 kt and 8.50 kt, respectively. This corresponds to an increase of 63.23%, which is arguably a big difference.

A similar pattern is observable for the estimated level of CO₂ emissions per unit of sales at the respective percentiles. The estimated level at the first percentile is $\ln(-0.81)$ and at the 99th percentile $\ln(-0.34)$. Taking the respective exponential function of the values leads to 0.44 kg CO₂ and 0.71 kg CO₂ emissions per US dollar sold. This corresponds with 60.0% also to an economically meaningful increase.

Using value added as a measure of CO₂ intensity reveals a difference of even 82.21%. The estimated level at the first percentile is $\ln(-0.27)$ and at the 99th percentile $\ln(0.33)$. Taking the

¹⁰The derived change in percentage is calculated by solving: $(\exp(\text{coefficient})-1)*100$.

respective exponential function of the values leads to 0.76 kg CO₂ and 1.39 kg CO₂ emissions per US dollar value added.

All in all, the results statistically and economically back Hypotheses 1 and 2 and show that also within industries, firms in upstream positions produce dirtier than firms in downstream positions.¹¹ The following section focuses on an instrumental variable approach to deal with possible sources of endogeneity.

4.4.2 Instrumental Variable Approach

The above-presented results on H1 and H2 are biased if a firm's environmental outcome affects its GVC position or if an omitted variable simultaneously affects a firm's upstreamness and the environmental outcome in production.

An example of reverse causality is where a firm introduces a clean product to the product mix to avoid reputational risks. Generally, consumers might be more likely to claim sustainable production on products they are familiar with, typically in a more downstream GVC position. To this end, the introduction of a clean product paves the way to get closer to customers, while reducing reputational risks.

A relatively similar threat to identification would arise if an omitted variable simultaneously affects GVC positioning and clean production. For instance, a firm's management has social preferences and favours simultaneously B2C (business to consumers) products in downstream positions and introduces a green strategy to improve the environmental footprint in production. In this case, the revealed effect occurs due to the social preferences of the management that are not covered in the firm level data.

I employ an instrumental variable estimation to overcome such endogeneity concerns. By construction, a firm can only influence its GVC position by changes in its product mix. The GVC positioning of each product is already beyond the scope of the management because it is measured at the industry level. However, to exclude any influence by the management, I instrument upstreamness with the natural logarithm of the advertising spending over sales among firms producing a similar main product measured at the five-digit level ($\ln advertising/SA$). The instrument does not include the respective spending and sales of the firm.

The instrument should meet two criteria to be valid. First, the instrument needs to be relevant, so the correlation between upstreamness and the instrument should be sufficiently high. I argue that the incentive of a firm for advertising increases along the GVC. Accordingly, firms producing the main product that is closer to final consumption spend more on advertising, on average. Generally, if a correlation is sufficient cannot finally be stated, but the correlation should be significant and a high F-statistic above 104.7 serves as a very conservative rule of thumb for validation (Lee et al., 2022). Second, a valid instrument meets the exclusion restriction. In line with the exclusion restriction, the instrument should not affect the environmental outcome of a firm, except through the GVC position. The latter is objectively difficult to evalu-

¹¹Going beyond upstreamness and taking Column (6) as a benchmark to measure the drivers of firms' clean production reveals that exporters, foreign-owned firms, more productive firms and firms active in R&D show lower CO₂ intensity. Conversely, state-owned firms and firms producing mining or agricultural products produce more CO₂-intensive. No effect is observable for purely manufacturing firms or service firms. Lastly, exposure to *EPS* does not relate to any changes in a firm's clean production.

ate. However, I argue that the exclusion of a firm's spending on advertising and sales fulfils the exclusion restriction because a firm does not have any influence on the value of the instrument. Moreover, if a firm decides to extend or reduce the product mix, this normally does not affect the main product. Accordingly, short-term changes due to management preferences do not enter the estimation and the respective instrumental variable remains exogenously given for a firm.

Table 4.4 includes the results of a 2-SLS estimation. The first column reports on the first stage, estimating the respective value of a firm's $\widehat{upstreamness}$. The specification does not include industry fixed effects because there is no sufficient correlation between the instrument and upstreamness at the first stage once the estimation focuses on the within industry variation. However, this is not completely surprising, because it is quite restrictive in the light of a high correlation of average advertising spending over sales estimated at the five-digit product level within an industry. Accordingly, the 2-SLS estimation does closely link to the specifications covered in Columns (1)-(3) of Table 4.3, overall linking to the results at the aggregated level by Shapiro (2021). Columns (2)-(4) of Table 4.4 refer to the main results of the 2-SLS estimation, including the estimated values of $\widehat{upstreamness}$ as an instrument for firms' GVC positions.

Table 4.4: 2-SLS Estimation

VARIABLES	(1) $\widehat{Upstream.}$ OLS	(2) CO2 2-SLS	(3) CO2/SA 2-SLS	(4) CO2/VA 2-SLS
(ln) advertising/SA	-0.123*** (0.007)			
$\widehat{Upstreamness}$		1.632*** (0.169)	1.215*** (0.152)	1.854*** (0.172)
EPS	-2.874*** (0.102)	3.905*** (0.573)	2.889*** (0.520)	4.162*** (0.587)
Export status	0.075*** (0.023)	-0.540*** (0.070)	-0.670*** (0.066)	-0.663*** (0.071)
Foreign ownership	0.166*** (0.046)	-0.509*** (0.136)	-0.512*** (0.133)	-0.759*** (0.144)
R&D dummy	-0.005 (0.031)	-0.060 (0.090)	-0.209** (0.087)	-0.300*** (0.096)
SOE	0.178 (0.132)	1.387*** (0.519)	1.218** (0.549)	1.181** (0.523)
(ln) productivity	0.018** (0.008)	0.029 (0.026)	-0.215*** (0.024)	-0.388*** (0.026)
(ln) assets	-0.012* (0.007)	0.990*** (0.023)	0.073*** (0.022)	0.116*** (0.024)
(ln) age	-0.029** (0.013)	0.342*** (0.044)	0.154*** (0.041)	0.103** (0.044)
Agricultural products	-0.294*** (0.037)	1.124*** (0.132)	0.864*** (0.128)	1.202*** (0.137)
Mining products	0.103** (0.043)	0.720*** (0.188)	0.988*** (0.185)	0.740*** (0.187)
Service products	0.053 (0.032)	-0.060 (0.115)	-0.225* (0.116)	-0.163 (0.120)
Exclusive manufacturing	-0.032 (0.036)	0.274** (0.125)	0.221* (0.126)	0.254* (0.129)
Observations	16,803	16,803	16,803	16,803
R-squared	0.410			
F-stat	283.69			
Year dummy	Yes	Yes	Yes	Yes
Industry dummy	No	No	No	No
State dummy	Yes	Yes	Yes	Yes

Robust standard errors in parentheses (clustered at the firm level)
 *** p<0.01, ** p<0.05, * p<0.1

The results of the first stage reveal that $(ln) advertising/SA$ significantly negatively correlates with a firm's upstreamness. Also, the F-statistic is 283.69 clearly above standard thresholds. Both patterns provide a high level of confidence that the instrument is relevant.

The positive relationship between firms' upstreamness and dirty production remains unchanged in all specifications. In all specifications, the positive effect is significant at the one-percent level, which again strongly supports H1 and H2.

As stated in Hypotheses 3 and 4, the negative effect of upstreamness on the environmental

outcome might differ with a firm's export status and exposure to EPS. The next section analysis the validity of these hypotheses.

4.4.3 The Moderating Roles of Export Status and Exposure to EPS

Columns (1) to (3) of Table 4.5 show the results of an interaction term between upstreamness and export status. Columns (4)-(6) include the interaction term between upstreamness and exposure to EPS.

Table 4.5: OLS estimation: Moderating effects of export status and EPS on upstreamness

VARIABLES	(1) CO2	(2) CO2/SA	(3) CO2/VA	(4) CO2	(5) CO2/SA	(6) CO2/VA
Upstreamness	0.225** (0.112)	0.206* (0.114)	0.270** (0.114)	0.988*** (0.298)	0.768*** (0.289)	0.886*** (0.299)
Export status	-0.364** (0.181)	-0.595*** (0.174)	-0.543*** (0.177)	-0.242*** (0.055)	-0.427*** (0.054)	-0.368*** (0.054)
EPS	-0.045 (0.237)	0.124 (0.233)	0.032 (0.228)	1.614*** (0.609)	1.307** (0.581)	1.335** (0.592)
Upstreamness x Export status	0.056 (0.081)	0.077 (0.077)	0.080 (0.079)			
Upstreamness x EPS				-0.809*** (0.298)	-0.579** (0.277)	-0.637** (0.288)
Foreign ownership	-0.284*** (0.109)	-0.337*** (0.110)	-0.514*** (0.111)	-0.282*** (0.109)	-0.336*** (0.110)	-0.513*** (0.112)
R&D dummy	-0.011 (0.070)	-0.174** (0.070)	-0.256*** (0.072)	-0.011 (0.070)	-0.172** (0.070)	-0.255*** (0.072)
SOE	1.374*** (0.460)	1.198*** (0.463)	1.195*** (0.359)	1.370*** (0.468)	1.194** (0.473)	1.190*** (0.367)
(ln) productivity	0.037* (0.021)	-0.207*** (0.020)	-0.383*** (0.020)	0.037* (0.021)	-0.208*** (0.020)	-0.384*** (0.020)
(ln) assets	0.947*** (0.019)	0.038** (0.018)	0.075*** (0.019)	0.947*** (0.019)	0.038** (0.018)	0.074*** (0.019)
(ln) age	0.199*** (0.034)	0.035 (0.033)	-0.048 (0.033)	0.201*** (0.034)	0.036 (0.033)	-0.047 (0.033)
Agricultural products	0.351*** (0.106)	0.219** (0.109)	0.431*** (0.111)	0.353*** (0.106)	0.219** (0.109)	0.430*** (0.111)
Mining products	0.651*** (0.192)	0.878*** (0.198)	0.698*** (0.190)	0.637*** (0.192)	0.866*** (0.197)	0.685*** (0.190)
Service products	0.032 (0.106)	-0.123 (0.110)	-0.054 (0.110)	0.034 (0.106)	-0.123 (0.109)	-0.054 (0.109)
Exclusive manufacturing	0.097 (0.114)	0.101 (0.116)	0.096 (0.116)	0.094 (0.113)	0.096 (0.116)	0.092 (0.116)
Observations	17,541	17,541	17,541	17,541	17,541	17,541
R-squared	0.627	0.341	0.365	0.627	0.341	0.365
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
State dummy	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses (clustered at the firm level)
*** p<0.01, ** p<0.05, * p<0.1

While the overall positive relationship between upstreamness and dirty production remains significant in all specifications, the interaction term of upstreamness and export status is not significant in any specification. Accordingly, there is no significant different slope for the relationship between upstreamness and dirty production depending on the export status of a firm observable. This finding does not back H3, pointing to possible differences in the magnitude of the technique effect along the value chain.

Conversely, the results of Columns (4)-(6) reveal a moderating role of demanding export markets on a firm's environmental performance. The interaction term between upstreamness and EPS is significant in all specifications, varying between five-percent and one-percent significance. This finding indicates that the main relationship between upstreamness and dirty production is conditional on the interaction because the positive slope diminishes with an increasing level of exposure to strong environmental regulation in foreign markets.

Figure 4.3 illustrates the moderating role of EPS on the relationship between upstreamness and CO₂ emissions per unit of value added (Column (6)).¹² The upper graph illustrates the

¹²The respective graphs for CO₂ emissions (Column (4)) and CO₂ emissions per unit of sales (Column (5))

predicted CO₂ per unit of value added depending on upstreamness for given levels of EPS. The lower graph illustrates the predicted CO₂ intensities depending on EPS for given levels of upstreamness.

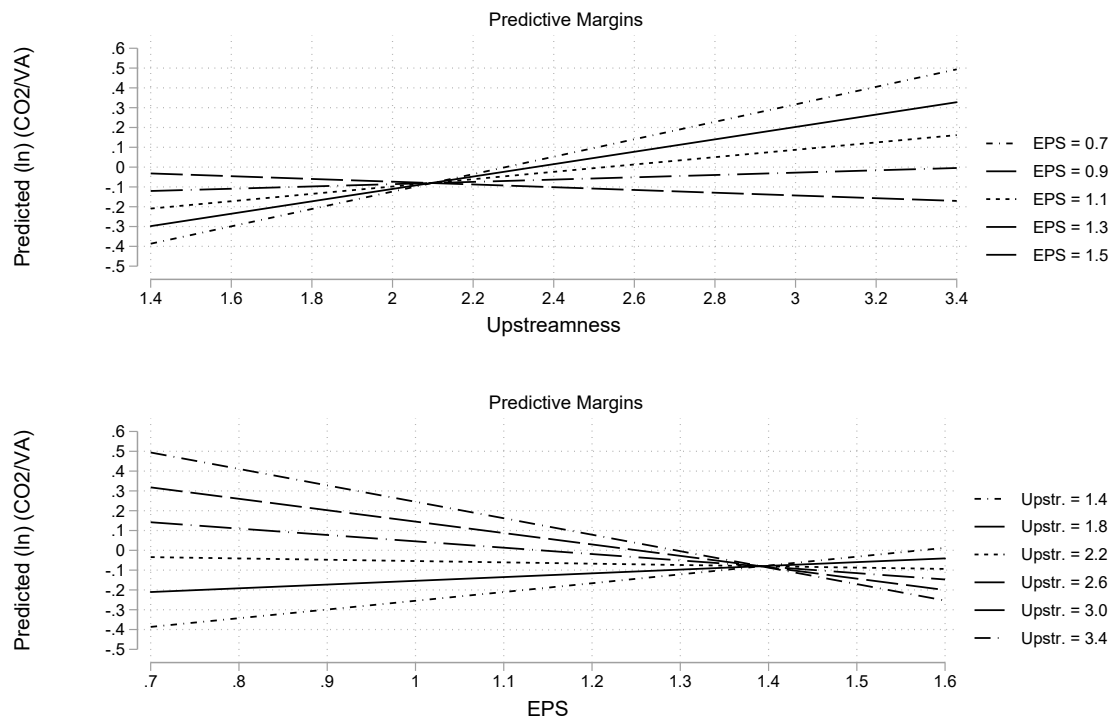


Figure 4.3: Predicted (ln) CO₂ per unit of value added for different combinations of upstreamness and EPS

An EPS score of 1.5 links to very strong environmental regulation in export destination markets. Given that firms face such a strong regulation, the slope of upstreamness is slightly negative, even if it is not significant. Conversely, an EPS score of very low 0.7 links to a strongly positive slope. The respective coefficient of upstreamness is 0.44 significant at the one-percent level. Holding the EPS score constant, it is also possible to derive the economic significance. For example, for firms exposed to weak environmental regulation in foreign markets ($EPS = 0.7$), a one-unit change in the upstreamness measure is associated with an increase of CO₂ emissions of 52.46%, CO₂ emissions per unit of sales of 43.72%, and CO₂ emissions per unit of value added of 55.29%.¹³

Interestingly, the relationship between *EPS* and dirty production becomes significantly positive once the interaction term between upstreamness and *EPS* is added. Also, the relationship between EPS and clean production is conditional on firms' GVC positions. As the lower graph of Figure 4.3 illustrates, firms' CO₂ intensity increases with EPS for firms in very downstream positions (upstreamness = 1.4). However, the derived coefficient of 0.44 is only significant at the 10-percent level. For firms in very upstream positions (upstreamness = 3.4), the coefficient

are part of the Appendix (Figures 4.5 and 4.6).

¹³For example, the respective coefficient of CO₂ emissions is calculated by solving: $0.988 - 0.809 \cdot 0.7 = 0.42$. The effect is given by: $(\exp(0.42) - 1) \cdot 100 = 52.46$.

turns negative to 0.83, again being significant only at the 10-percent level. In line with the only slight significance and given that a one-unit change of EPS relates to a difference in exposure going slightly beyond the difference of the minimum and maximum value observed in the sample, the economic significance should not be over-interpreted.¹⁴ Still, these relationships indicate some specialisation in dirty production in downstream positions.

All in all, the results revealed in Table 4.5 strongly back Hypothesis 4 and its economic relevance. This findings indicates that the relationship between upstreamness and dirty production diminishes with EPS for firms in upstream positions. Accordingly, firms in upstream positions seem to environmentally benefit outstandingly from exposure to strong environmental regulations in foreign markets. This insight links to the adoption of more efficient production techniques to remain competitive with firms in environmentally demanding markets, trade-induced learning-by-exporting effects, demand-pull, and regulation-push especially important for firms being further removed from the technology frontier in upstream positions. Conversely, firms in downstream positions show dirtier production with increased exposure to strong environmental regulation in foreign markets. The latter links to a specialisation in dirty production in line with Acemoglu et al. (2014). The next section focuses on the robustness of the key results.

4.4.4 Robustness

Unfortunately, not all firms report on their energy consumption in physical energy units. Accordingly, it is only possible to calculate annual CO₂ emissions for a subset of firms covered in Prowess. However, most firms report on their energy spending in US dollars.¹⁵ Energy costs are widely used in the literature to measure firms' environmental performances, for example, Eskeland and Harrison (2003) and Batrakova and Davies (2012). Cole et al. (2008) also use energy costs to proxy firms' environmental performance. However, they emphasise that their dependent variable should ideally capture a firm's emissions. I follow this suggestion in the main specifications because there are two main drawbacks of using energy costs. First, price changes in energy costs result in changes on the environmental performance measure, even if it does not affect a firm's environmental performance. Second, switching to cheaper energy sources results in an improvement of the measure, even though the newly used energy source can show a worse or better CO₂ footprint. Nonetheless, both proxies are highly correlated, which motivates this robustness check. Table 4.6 reports on the results once energy costs are used to calculate firms' clean production in absolute and relative terms. Columns (1)-(3) connect to the main specifications on the relationship between upstreamness and dirty production discussed in Section 4.4.1. Columns (4)-(6) link to the main results outlined in Section 4.4.3 on the moderating role of exposure to EPS.

¹⁴For example, for firms in very downstream positions (upstreamness = 1.4), a one-unit change in the EPS measure is associated with an increase of CO₂ emissions of 61.83%, CO₂ emissions per unit of sales of 64.28%, and CO₂ emissions per unit of value added of 55.77%. Turning to very upstream positions, the sign of the relationship between EPS and clean production shifts positively. For example, for firms in very upstream positions (upstreamness = 3.4), a one-unit change in the EPS measure is associated with a decrease of CO₂ emissions of 67.91%, CO₂ emissions per unit of sales of 48.4%, and CO₂ emissions per unit of value added of 56.43%.

¹⁵In addition, using energy costs as dependent variable does not require any assumption about the CO₂ conversion factor, e.g., the emissions per kwh can vary substantially between regions and time.

Table 4.6: OLS estimation: Robustness checks

VARIABLES	(1) ENE	(2) ENE/SA	(3) ENE/VA	(4) ENE	(5) ENE/SA	(6) ENE/VA
Upstreamness	0.344*** (0.069)	0.340*** (0.064)	0.424*** (0.072)	1.089*** (0.210)	0.829*** (0.195)	1.012*** (0.214)
EPS	0.141 (0.127)	0.236** (0.119)	0.207* (0.123)	1.723*** (0.402)	1.274*** (0.370)	1.455*** (0.395)
Upstreamness x EPS				-0.798*** (0.194)	-0.524*** (0.180)	-0.630*** (0.193)
Export status	0.145*** (0.034)	-0.152*** (0.032)	-0.076** (0.032)	0.145*** (0.034)	-0.152*** (0.032)	-0.075** (0.032)
Foreign ownership	0.154** (0.062)	-0.025 (0.060)	-0.167*** (0.062)	0.155** (0.062)	-0.024 (0.060)	-0.166*** (0.062)
R&D dummy	0.069* (0.039)	-0.121*** (0.038)	-0.191*** (0.039)	0.069* (0.039)	-0.122*** (0.038)	-0.191*** (0.039)
SOE	0.746*** (0.264)	0.678*** (0.220)	0.779*** (0.166)	0.747*** (0.265)	0.678*** (0.221)	0.779*** (0.166)
(ln) productivity	-0.014 (0.014)	-0.301*** (0.012)	-0.487*** (0.014)	-0.014 (0.014)	-0.301*** (0.012)	-0.486*** (0.014)
(ln) assets	0.812*** (0.011)	-0.121*** (0.010)	-0.073*** (0.010)	0.812*** (0.011)	-0.121*** (0.010)	-0.073*** (0.010)
(ln) age	0.212*** (0.019)	0.066*** (0.018)	0.003 (0.019)	0.213*** (0.019)	0.067*** (0.018)	0.004 (0.019)
Agricultural products	0.561*** (0.077)	0.432*** (0.072)	0.614*** (0.077)	0.565*** (0.077)	0.435*** (0.072)	0.617*** (0.077)
Mining products	0.218** (0.104)	0.409*** (0.102)	0.280*** (0.105)	0.206** (0.104)	0.402*** (0.103)	0.270** (0.105)
Service products	0.082 (0.080)	0.006 (0.077)	0.034 (0.078)	0.086 (0.080)	0.009 (0.077)	0.038 (0.078)
Exclusive manufacturing	0.027 (0.082)	0.135* (0.080)	0.115 (0.080)	0.027 (0.083)	0.135* (0.080)	0.116 (0.080)
Observations	42,762	42,762	42,762	42,762	42,762	42,762
R-squared	0.632	0.375	0.416	0.632	0.375	0.416
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
State dummy	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses (clustered at the firm level)

*** p<0.01, ** p<0.05, * p<0.1

The relationship between upstreamness and environmental performance is statistically significant at the one-percent level in all six specifications. In addition, the interaction between upstreamness and EPS is significant in all three specifications. To summarise, the robustness checks back prior results on H1, H2, and H4. Accordingly, firms in downstream positions show significantly cleaner production and exposure to strong environmental regulation in export markets diminishes the negative effect of upstreamness on clean production. The last section concludes the overall results of the study.

4.5 Conclusion

A large share of India's population still lives in poverty. Economic growth is essential to eliminate poverty but corresponds to a higher energy demand. Higher energy demand strongly correlates to higher CO₂ emissions, a nexus that has not been sufficiently broken. Even though the per capita CO₂ emissions of India are relatively low on global scale, the country is the third largest global emitter of CO₂. Although industrialised countries are responsible for the majority of historical CO₂ emissions, successes in developing countries, including India, are crucial if there is any hope of fulfilling the Paris Agreement's target of limiting global warming to well below 1.5°Celsius. This is mainly because most emissions growth originates from this subset of world's economies (Copeland et al., 2022).

To this end, regional and global decision makers need to understand the determinants of firms' environmental efficiency in production. Shapiro (2021) reveals that industries in downstream GVC positions emit less CO₂ per unit of output. However, even in narrowly defined industries, firms differ substantially, for instance in their productivity and product mix. I empir-

ically contribute to the literature on the understanding of the drivers of clean production, more precisely on the question of how firms' GVC positioning relates to its environmental outcome.

The derived results show that Indian manufacturing firms occupying upstream GVC positions emit significantly more CO₂ and report worse CO₂ intensities, measured as CO₂ per unit of sales, and as CO₂ per unit of value added. A change in the upstreamness measure by one unit - such as switching from the average GVC position of firms in the *textiles* industry to the *basic metals* industry - increases the estimated CO₂ emissions by 28.15%, CO₂ per unit of sales by 28.87%, and CO₂ per unit of value added by 35.39%. These key findings are robust against a 2-SLS estimation.

In addition, the empirical results reveal that exposure to foreign EPS negatively moderates the relationship between upstreamness and dirty production. Firms in upstream positions are, on average, further removed from the technology frontier and have to adopt more efficient production techniques to remain competitive in environmentally demanding markets abroad. These upstream firms can also disproportionately benefit from trade-related positive drivers of their clean production such as learning-by-exporting, regulation-push, and demand-pull. Interestingly, for firms in downstream positions, environmental performance deteriorates with increased exposure to EPS in export markets - a finding linked to specialisation in dirty production (Acemoglu et al., 2014). Notably, the negative relationship between upstreamness and clean production does not differ with the firm's export status.

My study contributes to the understanding of the determinants of firms' clean production in developing countries. Copeland et al. (2022) emphasise that the relationship between upstreamness and dirty production is observable in countries at all stages of development. I would expect similar results using firm level data for advanced countries. However, I expect that the moderating role of EPS in foreign markets might distinguish between studies using data for advanced countries. Firms occupying upstream positions and already facing strong domestic environmental regulation might not have to step up to new production techniques, even if they encounter strong EPS abroad. Such an analysis could represent part of a future research agenda. Moreover, in this paper, I have not touched on the role of indirect emissions. The relative importance of indirect emissions amplifies with downstreamness and it would be interesting to investigate whether the revealed upstreamness is also observable for indirect emissions (Copeland et al., 2022).

The key results have different implications for a firm's management and political decision makers. First, management can improve the overall environmental performance by introducing relatively clean products in downstream positions. A switch of the product mix to include cleaner products does not require any technological adoption and might be an attractive tool for the management to improve the general perception of stakeholders on sustainable production, such as when publishing statistics relating to CO₂ emission intensity, for outside investors. Arguably, the switch to downstream products is a form of greenwashing because it does not require the firm to make any fundamental changes in its processes - merely, in its product mix. Accordingly, this strategy is open to criticism by more sophisticated kind of stakeholder - those able to monitor the firm's performance at the product level.

Second, regional decision makers have an incentive to attract downstream industries to

improve their regional CO₂ balance sheet. However, on a global scale, the negative effect of GHG emissions on global warming does not depend on the location of emissions. Accordingly, and in line with the environmental bias of trade policy revealed by Shapiro (2021), tariffs for downstream industries should be reduced, bolstering support for them relative to upstream industries. Currently, the pattern is completely reversed, leading to an implicit subsidy for the relatively CO₂-intensive upstream industries.

Third, regulators should position the spotlight on the CO₂ intensity of upstream industries, where more energy is required to produce one unit of value added. The issue is how to incentivise consumers and other stakeholders interested in sustainable production, to expend higher efforts to monitor these environmental outcomes for upstream GVC positions, where end-consumers may be less directly invested in the products. Some of these upstream industries are tagged as hard to decarbonise, e.g. chemicals, cement or steel production. However, this does not preclude regulators from applying specific measures. One approach would be to reduce or eliminate the implicit subsidy for upstream industries by decreasing tariffs for downstream positions. Another, would be to establish an appropriate CO₂ price mechanism and to incentivise environmentally-friendly inputs such as renewable energies, renewable natural gas or green hydrogen. A judicious use of these measure could accelerate the green transition of these industries.

Lastly, monitoring global efforts on CO₂ reduction, multilateral institutions should consider differences in the average GVC positions of individual countries. Upstream industries generally report reduced environmental efficiency, but they are integral to GVCs, whose final production stages are often located in other – more developed - countries. The latter depend on these inputs. Accordingly, these countries are indirectly contributing to global pollution, when the GVC is viewed in its entirety. A comprehensive assessment of environmental footprints - consumption-based evaluation vs. production-based evaluation - could help overcome this distortion. Additionally, the application of a price which would correct for the environmental externality, for example CO₂ border adjustment taxes, would provide an incentive to downstream firms to push for sustainable production along the entire GVC.

4.6 Appendix

4.6.1 Calculation of CO₂ emissions

The calculation of firms' CO₂ emissions in production follows Barrows and Ollivier (2018) and Barrows and Ollivier (2021). The Prowess database includes a special module on firms' energy consumption. Quite uniquely, firms in India are obliged to report and monitor their energy consumption in a very detailed way. The obligation goes back to the 1988 amendments to the Companies Act, Section 217(1)(e).

The energy consumption database includes annual information about a firm's energy consumption split by energy type. Each entry is limited to a specific energy source. Hence, for firms consuming several energy types within a year, multiple entries are part of the database. For this study, I use the firm-level variables *energy_name*, *energy_cons_qty* and *energy_cons_unit*. By having information about the energy source used, the quantity consumed and the unit of the energy consumption it is possible to use the US EPA 2012 Climate Registry Default Emission Factors to transform energy consumption into CO₂ emissions. Figure 4.4 illustrate the respective emission factors. Next, I sum up the respective annual CO₂ emissions and collapse the database to a single annual firm-level entry. Notably, almost all firms considered in the regression analysis consume electricity (99.7%). In line with, Barrows and Ollivier (2021) 951 g CO₂ per kwh is assigned for electricity consumption, which is the average intensity for grid electricity in the period 2000 to 2010. Unfortunately, there is no more granular data available. Beyond electricity consumption, coal is with 25.08% a widespread energy source.

Barrows and Ollivier (2018) describe the major challenges in defining emission factors to a given energy source. First, firms report their energy use in different units, e.g., coal in kg or tons. Accordingly, the quantities consumed are standardised. However, for around 1% of energy consumption entries, the units cannot be standardised. Second, the energy consumption is merged with the EPA emission factors. Unfortunately, it is not possible to assign an emission factor to all energy source unit pairs. For instance, some firms misreport their energy consumption, e.g., stating electricity consumption in litres. In this example, a data cleaning would error-prone because the consumption could be in kwh, mwh or gwh. Such an issue occurs for around 17%. Third, in around 2% of the cases, the unit of the energy consumption does not match a CO₂ factor. For instance, firms report firewood consumption in cubic metres. In such a case, it is not possible to determine a CO₂ factor because the density of firewood varies substantially.

Table A.1
CO₂ emission factors.

Energy Source (1)	Kg CO ₂ per Unit of Energy Source (2)	Unit of Energy Source (3)	Kg CO ₂ per MMBTU of Energy Source (4)
Acetylene	.1053	scf	71.61
Agricultural Byproducts	974.9	short ton	118.17
Anthracite	2597.82	short ton	103.54
Biogas (Captured Methane)	.0438	scf	52.07
Coke	2530.59	short ton	102.04
Coke Oven Gas	.0281	scf	46.85
Distillate Fuel Oil No. 1	10.18	gallon	73.25
Distillate Fuel Oil No. 2	10.21	gallon	73.96
Electricity			278
Fuel Gas	.0819	scf	59
Kerosene	10.15	gallon	75.2
Kraft Black Liquor	1131.11	short ton	94.42
LPG	5.79	gallon	62.98
Lignite	1369.28	short ton	96.36
Lubricants	10.69	gallon	74.27
Motor Gasoline	8.78	gallon	70.22
Naptha (<401 deg F)	8.5	gallon	68.02
Natural Gas (US average)	.0545	scf	53.02
Petroleum Coke (Liquid)	14.64	gallon	102.41
Petroleum Coke (Solid)	3072.3	short ton	102.41
Propane (Liquid)	5.59	gallon	61.46
Residual Fuel Oil No. 6	11.27	gallon	75.1
Solid Byproducts	2725.32	short ton	105.51
Wastewater Treatment Biogas			52.07
Waxes	9.57	gallon	72.6
Wood and Wood Residuals	1442.64	short ton	93.8

Notes: The first column lists the energy source as named by the EPA. Prowess does not use exactly the same naming convention, so we mapped by hand these energy types to the energy types listed in Prowess. The second column reports kg CO₂ associated with a given unit of energy type in column 1, where the unit is reported in column 3. For most energy types, we use the CO₂ intensity listed in column 2. However, for some observations, we were unable to standardize units across the two datasets. In some cases, we were able to use an alternative CO₂ intensity reported per mmbtu. We list this alternative CO₂ intensity in column 4.

Figure 4.4: CO₂ emission factors (Barrows and Ollivier, 2018, p.149)

4.6.2 Additional statistical outputs

Table 4.7: Correlations of dependent variables and upstreamness

	(1)	(2)	(3)	(4)
(1) (ln) CO ₂ emissions	1.00			
(2) (ln) CO ₂ /SA	0.58	1.00		
(3) (ln) CO ₂ /VA	0.60	0.93	1.00	
(4) Upstreamness	0.12	0.03	0.08	1.00

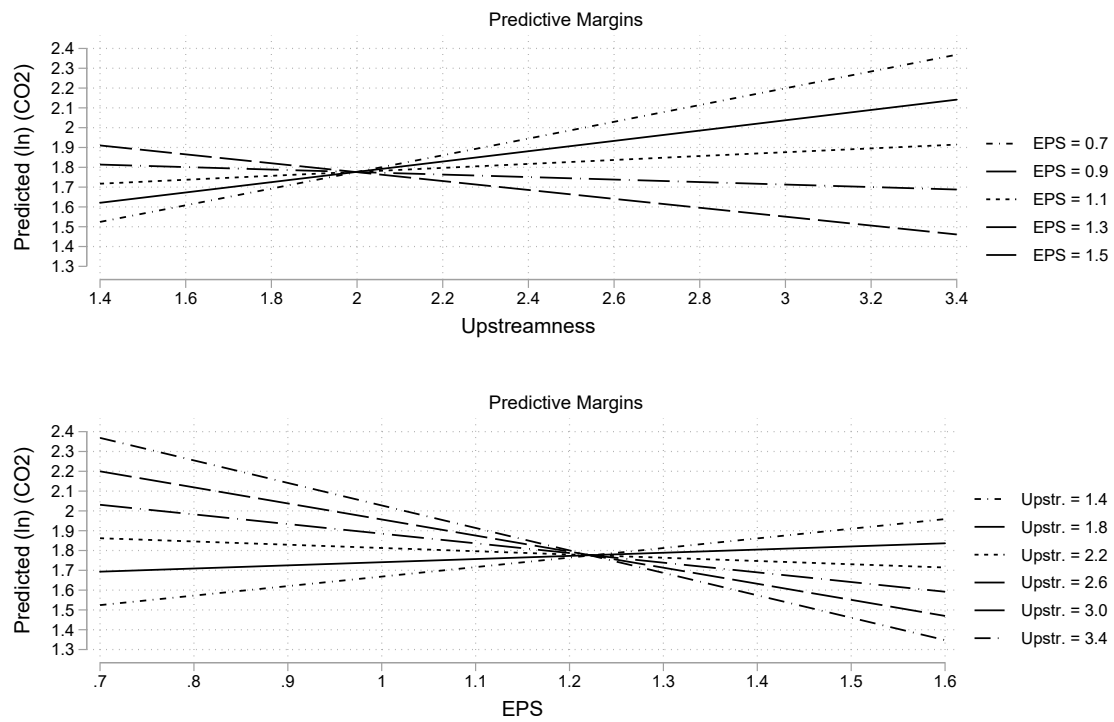


Figure 4.5: Predicted (ln) CO₂ emissions for different combinations of upstreamness and EPS

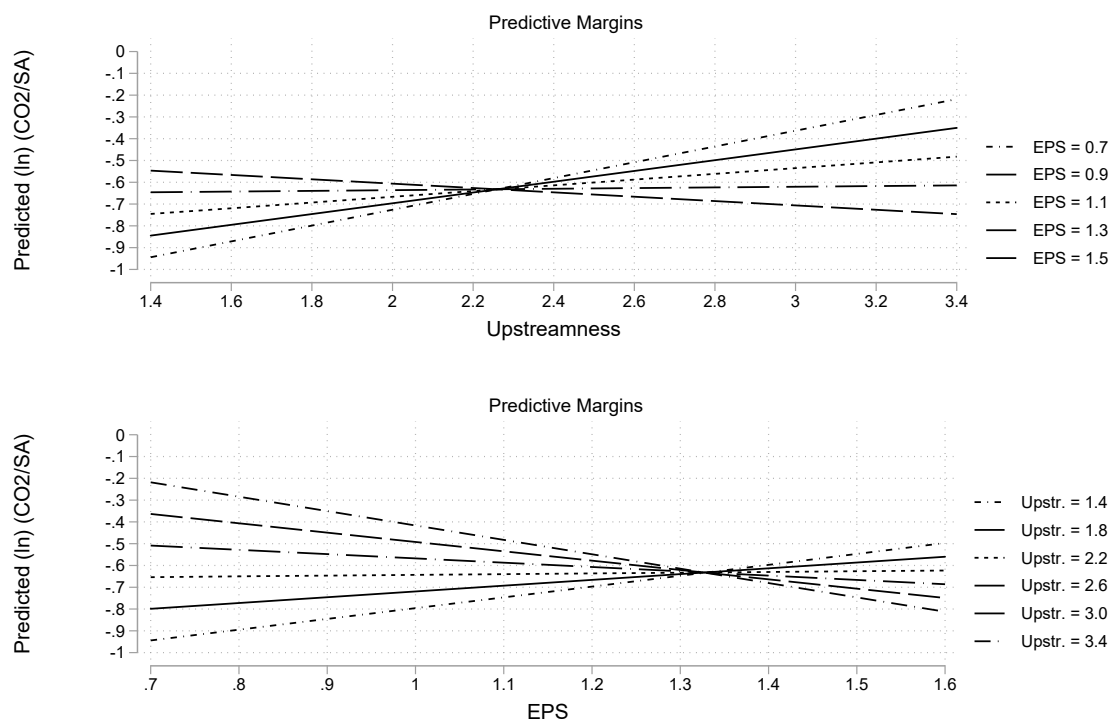


Figure 4.6: Predicted (ln) CO₂ emissions per unit of sales for different combinations of upstreamness and EPS

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Chapter 5

Corporate Social Responsibility along the Global Value Chain^{* †}

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Abstract

Locating substantial parts of the production process in developing and emerging economies, many firms face an increasing demand by stakeholders for Corporate Social Responsibility (CSR) along their value chains. Contractual incompleteness between firms and their suppliers at different stages of production can exacerbate the ability to meet these demands. We analyze a model of sequential production with incomplete contracts where CSR by independent suppliers differentiates the final product in the eyes of caring consumers. Progressing down the value chain, our model predicts an increasing CSR profile from upstream suppliers with low CSR to downstream suppliers with higher CSR. We confirm this prediction using Indian firm-level data – computing a firm’s value chain position by combining its product-level sales information with the World Input-Output Database. We find that more downstream firms report higher CSR expenditures as measured by a combination of staff welfare spending and social community spending.

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5.1 Introduction

Participation in global value chains (GVCs) is often considered a path to development for low and middle-income countries (OECD/WTO, 2013; World Bank, 2020). Concerns about negative social and environmental impacts of GVCs in those countries are, however, widespread and boosted by tragedies such as the Rana Plaza collapse in 2013. Consumers have responded to these concerns by becoming increasingly vocal about their demand for ethical standards along the *entire* value chain. With large parts of today’s value chains located in developing and emerging economies characterized by high leniency with regard to environmental or labor regulation and/or enforcement, this requires that suppliers invest in Corporate Social Responsibility (CSR). CSR investments – by definition – extend beyond local legal requirements (e.g., McWilliams and Siegel, 2001) and are therefore key for meeting the demands of an ever growing number of ethically concerned consumers and, more broadly, for the general acceptance (or not) of globalized production in the public debate.

Persistent and sizable compliance issues concerning labor and environmental practices in the value chains of a large number of firms indicate, however, how difficult it can be for firms to impose CSR levels on their international suppliers, e.g., through legally binding codes of conduct (e.g., Locke, 2013b). At the same time, relying on the individual self-interest of a large number of independent suppliers at different positions along the value chain is unlikely to deliver optimal levels of CSR (from the perspective of the firm).

With this paper, we contribute to a better understanding of the factors that drive CSR along the global value chain. More specifically, we ask the following questions: Which role does the value chain position of suppliers play in their CSR investments? What are the resulting patterns of CSR along a value chain, from upstream to downstream production stages?

We make two main contributions. First, we analyze a model of non-contractible CSR investments by suppliers in a sequential production process (a value chain). In our model, CSR investments of suppliers in the Global South provide horizontal and vertical product differentiation when selling the final product to caring consumers in the Global North. We find that the equilibrium CSR investments are low in upstream stages, increase along the value chain, and peak at the most downstream stages. Second, we test this prediction employing Indian firm-level data. Combining detailed information on a firm’s product mix with the World Input-Output Database (WIOD), we construct a measure of a firm’s GVC position to empirically investigate how it affects a firm’s monetary CSR spending. Our empirical analysis supports the theoretical prediction: CSR expenditure increases along the value chain.

In our model, firms and consumers are located in the Global North, while suppliers are located in the Global South and operate under lenient regulation. We introduce a group of ‘caring’ consumers who appreciate a product’s ‘ethical quality’ embodied in environmental and welfare improvements (CSR) implemented by suppliers along the value chain.¹ In line with the findings in Bartling et al. (2015), in our model, CSR along the value chain provides product differentiation for the final product. Higher CSR investments by suppliers therefore allow the firm to charge a higher markup.²

A central premise of our analysis is that suppliers make their decisions on CSR in an environment characterized by incomplete contracts: the firm selling the final good to consumers cannot write binding contracts prescribing production standards in supplier factories. We argue in detail in Section 5.2.1 that for the case of CSR, contracts are incomplete as the supplier’s action is “observable, but not verifiable”

¹Surveys (e.g., O’Rourke, 2005, and Loureiro and Lotade, 2005) as well as field experiments with real purchasing decisions (e.g., Hiscox and Smyth, 2011, and Hainmueller et al., 2015) suggest that consumers do care about the ethical content of their consumption and in fact have a higher willingness to pay for ‘ethical’ products.

²This implies that we abstract from massive consumer boycotts or well-mediatised scandals, which depress demand of targeted firms. Such events may play a role for generating or expanding the group of caring consumers. We take the existence of caring consumers as given and rather model CSR investments along the value chain as opportunities to increase the perceived (ethical) quality of the product by incrementally contributing CSR from production stage to production stage (see Section 5.2.2.1).

(Hart and Moore, 1999, p. 118). Central to the argument is the difference between circumstantial evidence on a supplier’s infringements of ethical standards (observability) on the one hand and, on the other hand, evidence that will hold in a court of law (verifiability). While circumstantial evidence can be sufficient for caring consumers to re-assess their valuation of the product and therefore demand, it is insufficient in a court of law, especially so in countries with weak legal institutions.³

We introduce the above elements – caring consumers and incomplete contractability of CSR – into a model of sequential production along the lines of Antràs and Chor (2013). We find an increasing profile of the suppliers’ equilibrium CSR investments along the value chain: while CSR investments at upstream stages are low, they increase along the value chain towards more downstream stages. This pattern arises because under incomplete contracts, the cumulative CSR investment in previous stages provides the supplier with an incentive to choose a higher CSR level. We derive the complete industry equilibrium with free entry and find that endogenizing the number of firms has important implications for identifying testable implications. While in the partial equilibrium (taking aggregate variables as given), CSR investments increase in the total expenditure on ethically differentiated goods, this effect vanishes in the industry equilibrium. This leaves us with a single and clear testable implication of our model: the increasing profile of CSR along the value chain, which we take to the data in Section 3.

Several policy implications directly emerge from our theory. First, as higher CSR levels at upstream stages encourage CSR investments at more downstream stages (sequential complementarity), policy interventions targeting CSR at upstream stages may benefit CSR along the entire value chain. Second, for governments aiming at decent work and economic growth (as specified in the UN’s Sustainable Development Goal 8), the fact that the more upstream stages of production feature the lowest CSR levels, provides an incentive to strategically focus industrial policy towards specialization in more downstream production stages. Third, policy initiatives like the EU Directive on Corporate Sustainability Due Diligence, the French Duty of Vigilance Law or the German Due Diligence Law shift the responsibility for supplier actions to firms. Our analysis hints at the limited ability of a firm to impose ethical standards on its suppliers and highlights that this problem is particularly severe for suppliers at upstream stages of production. Future due diligence regulation should take this asymmetry along the value chain into account.

We test our model’s prediction using the Indian firm-level dataset *Prowess* provided by the Centre for Monitoring Indian Economy (CMIE), which has been used by Goldberg et al. (2010a,b); De Loecker et al. (2016); Bos and Vannoorenberghe (2018) as well as Barrows and Ollivier (2021), among others. It is a special feature of this dataset that it contains information on the firms’ *staff welfare spending* as well as *social community spending*. We use these items to construct a measure of a firm’s CSR spending in monetary units, which we observe for 15,512 medium-size and large firms between 2000 and 2013 in India.

Our approach to computing a firm’s value chain position parallels the procedure in Chor et al. (2021). First, we use the World Input-Output Database (WIOD) and apply the methodology from Antràs et al. (2012) and Antràs and Chor (2018) to compute the yearly upstreamness of each Indian industry. Second, to each product in a firm’s portfolio, we assign the value of annual upstreamness of its industry and calculate the firm’s value chain position, its upstreamness, as the sales-weighted average of its products’ upstreamness values.

We estimate the relationship between a firm’s value chain position on its CSR expenditure. In our analysis, we control for a large set of firm-level determinants of CSR identified in the literature (e.g.,

³Crifo and Forget (2015) survey a literature on CSR in management sciences and industrial organization. They list imperfect competition and contract incompleteness as central drivers of CSR (see, e.g., their Figure 1, p. 114). Schiller (2018) motivates his purely empirical work alluding to the same notion of incomplete contracts: the inability of a firm to fully control CSR investments of its suppliers. Moreover, there is a recent and quickly expanding literature on relational contracts in developing countries surveyed in Macchiavello (2021), which lends support to our modeling on incomplete contracts in value chains involving developing and emerging economies.

Newman et al., 2018; Görg et al., 2018; Schiller, 2018). These include a measure of internationalization (share of exports in total sales), exposure to more demanding customers (measured by the fraction of exports to OECD countries), local embeddedness (share of domestically sourced inputs), firm size (total sales), age and firm ownership (dummies for state owned and foreign owned firms). Importantly, we control for the possibility that wage levels may vary systematically along the value chain using a firm-specific wage measure that combines industry-level information on labor compensation with a firm’s product mix.⁴

In our estimations, we rely on two different types of variation. First, in a cross-sectional specification, we control for several established firm-level drivers of CSR and industry-year as well as state fixed effects. This approach exploits variation in the value chain position of firms that share the same main industries. Second, in a more demanding specification, we exploit the time dimension of our data. By including firm fixed effects, we identify the effect from changes in a firm’s GVC position over time. In both cases, we find strong support for our model’s prediction: more downstream firms have higher CSR levels. Comparing firms at the 5th and the 95th percentile, our preferred specification indicates that predicted CSR spending is 55.3% higher for the downstream firm compared to the upstream firm.

Our results also hold in several robustness checks. In one of them, we address the possible concern that more downstream producers might simply be more visible to final consumers and therefore face higher pressure to invest in CSR. We control for visibility by adding marketing and advertising expenses as an additional variable. We also smooth CSR spending over two years to control for lumpy CSR spending.

Our work relates to the recent literature studying the “globalization backlash”, the massive skepticism economic globalization encounters in many countries (Pavcnik, 2017), which is surveyed in Colantone et al. (2022). We are interested in an additional and complementary source of skepticism towards globalization: the ongoing violation of ethical standards in international production - attracting criticism from consumers and actors in civil society. Moreover, while the literature above focuses on public regulation, we are interested in patterns of voluntary self-regulation along international value chains.

There are several strands of literature that focus on the (consequences of) the demand for ethical minimum standards in international value chains. In the absence of effective international regulation (Battaglini and Harstad, 2020), this demand manifests itself as pressure on firms to self-regulate international production, a process Baron (2003) terms *private politics*. In Baron (2012), he argues that key actors of private politics are advocacy NGOs which use both confrontational strategies (like consumer boycotts) as well as cooperative approaches (like labels) to directly influence the actions of firms (instead of affecting government policies in the case of *public politics*). Our analysis therefore relates to the literature on labels, with the fair trade label being the best documented and most researched case in point.⁵ The other strand of literature is a recent and expanding literature on the role of international advocacy NGO activity for international production and development.⁶ The latter is more focused on NGO campaigns and consumer boycotts. Our object of study, CSR along the value chain, is closer to the former, as it emphasizes the opportunity for firms to increase demand and markups, rather than the risk

⁴Controlling for firm-specific wages addresses the following concern: If staff welfare spending is a part of the overall compensation package, downstream firms might offer systematically higher pay due to higher skill intensity, for example. A negative correlation between upstreamness and CSR spending (as measured in part by staff welfare spending) could then be interpreted as actually reflecting the negative relationship between upstreamness and employee compensation.

⁵The fair trade label is studied empirically, among others, by Hainmueller et al. (2015), de Janvry et al. (2015), and Dragusanu et al. (2022), and theoretically by Stähler and Richardson (2014) and Podhorsky (2015). See Dragusanu et al. (2014) for a survey. For studies of labels more generally, see Fischer and Lyon (2014), Heyes and Martin (2017), as well as Poret (2019).

⁶See, e.g., Aldashev and Verdier (2009), Aldashev and Verdier (2010), Aldashev et al. (2015), Krautheim and Verdier (2016), Koenig et al. (2021), Fontagné and Limardi (2020).

of facing a devastating boycott. In fact, the provision of labels by NGOs can be seen as a mechanism to strengthen the positive effect of CSR investments on demand. In our paper, we take this positive effect as a given and study how it shapes CSR investments along the value chain.⁷

There is a recent and quickly expanding literature on relational contracts in developing countries surveyed in Macchiavello (2021), which supports our notion of the relevance of incomplete contracts in sourcing relationships especially involving developing and emerging economies.⁸ Most informative for our modeling (see Section 5.2.3.1), Cajal-Grossi et al. (2020) show that suppliers in the Bangladeshi garment sector obtain higher prices when selling to relational buyers than when selling to spot buyers. While these papers provide valuable insights into the contracting relationships to overcome contractual incompleteness in an environment with weak legal institutions, they do not analyze the relation to CSR investments.

Our theory is rooted in the large literature studying the role of incomplete contracts for the international boundaries of the firm, based on the seminal contributions of Antràs (2003) and Antràs and Helpman (2004), surveyed in Antràs and Yeaple (2014) and Antràs (2016). We build our modeling on Antràs and Chor (2013) where a firm’s value chain is modeled as a sequential production process. Like most of this literature, they focus on the integration vs. outsourcing decision along the value chain. Costinot et al. (2013) also model international sourcing as a sequential production process, but without incomplete contracts. They focus on the endogenous fragmentation of the value chain across countries. We abstract from both the international make-or-buy decision and the allocation of tasks across countries. Our main focus, in contrast, is on CSR investments along a sequential value chain characterized by incomplete contracts. Our modeling opens up both the theoretical and the empirical toolkit of the literature on international sourcing with incomplete contracts to the analysis of social and environmental issues in globalized production that feature prominently in the public debate. Closest to our paper in this respect is recent work by Herkenhoff and Krauthaim (2022), who analyze a model featuring caring consumers, consumer boycotts and incomplete contracts to study the effects on the international make-or-buy decision in a setting with a single supplier. We, in contrast, study the determinants of CSR investments based on a model that features a continuum of suppliers along a sequential value chain. This allows us to study the effect of a supplier’s value chain position on its CSR investments and therefore the profile of CSR along the value chain.

There is an extensive empirical strand of this literature, with Alfaro et al. (2019) being a recent example. These papers directly relate to the theoretical underpinnings, where incomplete contracts lead to underinvestment in a relationship-specific non-contractible variable (inputs, quality-adjusted inputs, etc.). As these non-contractible variables are notoriously difficult to observe in the data, the empirical studies turn to the observable optimal response of the firm to the underinvestment: the integration vs. outsourcing decision. Antràs and Chor (2013), for example, investigate the role of upstreamness of a supplier for its – empirically unobservable – quality-adjusted investment. To generate testable implications, they therefore turn to the observable optimal response of the firm to the underinvestment: depending on the upstreamness of the supplier, either integration or outsourcing delivers the right incentives minimizing the negative consequences of the underinvestment. Our empirical analysis complements the existing literature as we, in contrast, directly observe the non-contractible variable of interest: CSR spending. This allows us to investigate more directly the role of the GVC position for supplier investments under

⁷Closest to our model in terms of the type of policy considered is Alfaro-Ureña et al. (2021) who develop a quantitative general equilibrium model to study the effects of responsible sourcing in origin countries based on data on affiliates of multinationals in Costa Rica.

⁸Macchiavello (2010) uses a model with incomplete contracts to study the effect of vertical integration on the pervasive use of subcontracting arrangements among small firms in developing countries. Casaburi and Macchiavello (2019) show how imperfect contract enforcement generates barriers to entry in the Kenyan dairy sector. Machiavello and Morjaria (2021) highlight the importance of long-term relational contracts in the Rwandan coffee sector. Brugués (2020) analyzes the role of imperfect contracts in the textile, pharmaceutical and cement sectors in Ecuador depending on market power.

incomplete contracts.

There is a large literature on CSR at the intersection of the fields of management science and industrial organization. Kitzmuller and Shimshack (2012), Crifo and Forget (2015), and Pisani et al. (2017) provide surveys of this literature. This includes a large body of empirical studies on CSR which mainly focuses on the effect, rather than the determinants, of CSR. We take a different angle, contributing to a better understanding of the determinants of CSR by analyzing the impact of a firm’s value chain position. Moreover, most of this literature uses indices combining qualitative measures obtained by mandatory CSR reporting of listed firms in developed rather than emerging economies (e.g., Marano and Kostova, 2016; Pisani et al., 2017). We, in contrast, use data from India, a key emerging economy, which not only allows us to construct a continuous monetary measure of CSR, but also to study the behavior of non-listed medium-sized and large firms.

Our empirical analysis complements a small number of empirical studies assessing the role of global value chain relationships for CSR. Noteworthy contributions are Schiller (2018) and Newman et al. (2018). Schiller (2018) uses data restricted to large publicly listed companies to show that corporate environmental and social policies of firms are transmitted to suppliers in their value chain and studies the effect of these policies on firm performance. He provides evidence that is consistent with the interpretation that despite incomplete contracts firms can still affect their supplier’s CSR choices to some extent. We, in contrast, are interested in how the limited control of a firm over its suppliers shapes their CSR choices.

Most related to our empirical analysis is Newman et al. (2018). They exploit CSR indicators that capture compliance with labor standards, community and management-related CSR practices to analyze the transmission of socially responsible behavior through trade in Vietnamese firms. They find that a firm’s CSR increases with exporting and importing, varying across export destinations. The internationalization of supply chain relationships therefore seems to matter for CSR activities of firms. Moreover, Newman et al. (2018) conjecture that in addition to the internationalization of buyer-seller relationships, the supplier’s position along the value chain may matter and control for it using firm fixed effects. We, in contrast, use a time-varying, firm-specific measure of a firm’s value chain position that allows us to directly measure the GVC position of a firm and to analyze its relationship to the firm’s CSR spending.

The remainder of the paper is structured as follows. Section 2 presents our theoretical analysis of CSR along the global value chain. Section 3 outlines our empirical analysis. Section 4 concludes.

5.2 A Model of CSR along the Global Value Chain

In this section, we incorporate consumer valuation for ethical production practices and CSR investment into a model of sequential production with incomplete contracts based on Antràs and Chor (2013). We assume that each firm in the Global North has a value chain with unit measure of required inputs, which are all provided by *independent* suppliers in the Global South, where environmental and labor regulation is insufficient from the perspective of caring consumers in the Global North. We derive the industry equilibrium of the model and show that our theory implies an increasing CSR profile along the value chain – a prediction which we take to the data in Section 3.

5.2.1 Incomplete Contractibility of CSR

Before turning to the outline of our model, we first plead the case for the relevance (and the type) of incomplete contracts for CSR along global value chains. Assuring sufficient CSR levels by suppliers is notoriously difficult to achieve. Nike’s response to the “sweatshop campaign” in the 1990s is probably the best documented and most researched case in point. Protests against work conditions in Indonesian supplier factories led Nike to implement compulsory, legally binding codes of conduct for all its sup-

pliers.⁹ Harrison and Scorse (2010) show that the campaigns caused an increase in the real wages in Indonesian factories manufacturing for Nike. Locke (2013a), however, shows that more than a decade after the introduction of legally binding codes of conduct combined with an auditing system, substantial compliance problems persisted in Nike’s supply chain. He analyzes data from factory audits of working conditions in more than 900 of Nike’s suppliers located across fifty countries and finds that, despite the fact that all suppliers are obliged to sign the codes of conduct and despite large investments into monitoring, there still is a substantial number of suppliers that are ranked as “noncompliant”. In Asia, the noncompliant suppliers even constitute the majority. While Nike is a particularly well-documented case in point, these problems are by no means specific to Nike or the footwear and apparel sector. Based on data from one of the world’s largest supply chain auditing firms containing 16,795 audits of 5,819 factories in 13 industries across 66 countries over a period of six years, Short, Toffel and Hugill (2016, 2020) document widespread violations of codes of conduct in areas like child labor, forced labor, working hours, occupational health and safety, the minimum wage and disciplinary practices.

In our view, this calls for a model of CSR along GVCs that explicitly accounts for *incomplete contracts* between a firm and its suppliers. One standard way of motivating contractual incompleteness is that it is prohibitively costly - if possible at all - to cover all contingencies in a contract. This does not seem to be a major concern in our context: codes of conduct and similar contracts can specify minimum social, labor and environmental standards. In the case of CSR investments, the contractual incompleteness stems from another standard argument: the actions of the supplier are “observable but not verifiable” (e.g., Hart and Moore, 1999). This means that it is costless (or at least relatively cheap) to determine what is going on in a supplier’s factory but is prohibitively costly to hold the supplier accountable for the induced losses in a court of law.

There are quite general and well-known problems with verifying labor and environmental standards implemented in production plants, especially so in low-regulation countries. Safety equipment may be distributed one day, but not the other, fire exits may be accessible one day, but blocked the other, workers may fear the loss of their jobs, if they report forced and excessive overtime, toxic waste may be disposed into a river when no-one is watching.¹⁰ It is nevertheless relatively cheap for, say, an advocacy NGO to talk to workers, measure toxins in waste water or send an undercover agent into a factory to find out about the actual production conditions. Such circumstantial evidence, possibly obtained by breaking domestic laws, is insufficient in a court of law. However, in many cases it is sufficient to convince caring consumers to re-assess their valuation of the product and to reduce demand.¹¹ Producing the type of evidence that would lead to a conviction of the supplier - though in principle possible - will in many cases be prohibitively costly to produce. It would require a massive and continuous presence of auditors on site and even then, there is no guarantee that they will win the cat-and-mouse game with local management. This highlights that the notion in the incomplete contracts literature that the action is “observable but not verifiable” (e.g. Hart and Moore, 1999) applies to CSR investments along GVCs.¹²

⁹In May 1998, Nike CEO Phil Knight famously made the following statement: “The Nike product has become synonymous with slave wages, forced overtime, and arbitrary abuse. I truly believe the American consumer doesn’t want to buy products made under abusive conditions.” (New York Times, 1998).

¹⁰For a vivid description of the typical problems of auditors in the field, see Locke (2013b), p. 35-37.

¹¹This is all the more so as NGOs are repeatedly reported to be the most trusted institutions among consumers before governments and the media. See, for example, the Edelman Trust Barometer for 2020, at <https://cdn2.hubspot.net/hubfs/440941/Trust%20Barometer%202020/2020%20Edelman%20Trust%20Barometer%20Global%20Report-1.pdf>.

¹²In our modeling, we assume for simplicity that the firm and consumers can observe the *actual* level of CSR by the supplier - but that it is not verifiable by a court. In case that some readers take issue with the notion that the *actual* CSR level is observable but non-verifiable, note that this assumption can be relaxed - further broadening the gap between the cost of observing and the cost of verifying. For the mechanics of our model to function, we do not need the firm and consumers to observe the *actual* CSR investments. The firm only needs to know the CSR level which consumers *observe* or *perceive* (however misguided their perception may be) and which they use to form their opinion on the ethical quality, $\varepsilon(\omega)$. This observable/perceived CSR level is what

5.2.2 Setup: Preferences and Technology

We now turn to the formal description and analysis of our model starting with preferences and technology. Preferences include the second key feature of our modeling – besides incomplete contracts for CSR discussed above: consumer valuation for CSR along the value chain. We first present and explain our modeling choices concerning the ‘production technology’ of perceived ethical quality of a final product and then turn to the production technology for physical output.

5.2.2.1 Preferences, CSR, and Perceived Ethical Quality

Consumers derive utility from the consumption of different varieties of a final consumption good. We assume that all varieties share the *same physical properties*. There are two types of consumers in the Global North, which we label *caring* and *non-caring* (Davies, 2005; Besley and Ghatak, 2007).

The group of caring consumers values the implementation of high labor and environmental standards in the production process. For them, higher standards along the value chain translate into a higher *perceived ethical quality* of variety ω , $\varepsilon(\omega) \geq 0$, which caring consumers value as well as the *physical units* of variety ω they consume, $q(\omega)$.¹³ The preferences of caring consumers are given by:

$$U = \left(\int_{\omega \in \Omega} [\varepsilon(\omega) q(\omega)]^\rho d\omega \right)^{1/\rho}, \quad (5.1)$$

where Ω represents the set of available varieties. This way of modeling quality is standard in the trade literature, see, e.g., Baldwin and Harrigan (2011) and references therein. For simplicity, we assume that ethical quality is the only means of differentiation across varieties.¹⁴ Non-caring consumers are indifferent about ethical quality and therefore only care about the physical quantities they consume. As we assume that all varieties are identical in terms of their physical properties, in their eyes, varieties are homogeneous. Their utility is given by:

$$U' = \left(\int_{\omega \in \Omega} q(\omega) d\omega \right)^\rho. \quad (5.2)$$

While varieties in equation (5.2) are perfect substitutes, positive CSR along the value chain allows the firm to sell to caring consumers with utility function given by equation (5.1). Doing so provides two sources of differentiation to the firm. The quality shifter $\varepsilon(\omega)$ provides vertical differentiation as it increases the utility obtained from consumption of one unit of variety ω . At the same time, a positive level of $\varepsilon(\omega)$ provides horizontal differentiation. In our model this can best be thought of as an ethical narrative of the firm that provides some degree of product differentiation compared to other ethical products. The degree of differentiation is governed by the parameter $\rho \in (0, 1/2)$.¹⁵

determines the surplus of the match - but it is obviously impossible to condition on it in a contract, e.g. by specifying a fine in response to perceptions of consumer or allegations by NGOs.

¹³There is ample empirical evidence that consumers care about the ethical content of their consumption and have a higher willingness to pay for ‘ethical’ products. The evidence stems from surveys (O’Rourke, 2005, and Loureiro and Lotade, 2005) lab experiments (Bartling et al., 2015) as well as field experiments with real purchasing decision (e.g., Hiscox and Smyth, 2011, and Hainmueller et al., 2015). Basu and Tzannatos (2003) and Cone (2013) provide evidence that this awareness is increasing over time.

¹⁴See Aghion et al. (2020) for a recent example of such a modeling approach.

¹⁵Restricting ρ to be smaller $1/2$ may seem to be an unusual assumption. The need for this assumption arises because the revenue function becomes convex in final output quantity $q(\omega)$ when demand is too elastic (large ρ), see eq. (5.16) in Section 5.2.4. This effect arises in our model because choosing a higher ethical quality shifts the demand function outward *without* raising the marginal cost of physical production, as is usually the case in the quality literature (e.g., Baldwin and Harrigan, 2011, and references therein). In Appendix 5.5.3 we show how this assumption can be easily relaxed by introducing a parameter $\nu \in (0, 1)$ representing the scope of (ethical) quality differentiation in the utility function used recently in Fan et al. (2015) and Bastos et al. (2018) as well as

The perceived ethical quality of variety ω , $\varepsilon(\omega)$, is determined by the environmental and labor standards implemented in the different production stages. We denote the implemented level of the standard at stage j by $s(j)$. We assume a sequential production process with $j = 0$ being the most upstream input and $j = 1$ the most downstream one. The level of CSR of the supplier at stage j is defined as the difference between $s(j)$ and the level of regulation in South, which we normalize to zero. Therefore, $s(j)$ also represents the level of CSR implemented by supplier j . We assume a constant marginal cost of CSR investment, c_s , which is identical across stages. The CSR levels across production stages shape the perceived ethical quality of variety ω :

$$\varepsilon(\omega) = \left(\int_0^1 s(j)^\alpha dj \right)^{1/\alpha}. \quad (5.3)$$

With the parameter $\alpha \in (0, 1)$, CSR levels across production stages are gross substitutes. This implies that perceived ethical quality is obtained by aggregating the CSR levels across all production stages. Because our assumption on α implies that we maintain some degree of complementarity between different stages, CSR investments that are homogeneously spread out over the entire supply chain lead to a higher level of perceived ethical quality than concentrating the investments in a small fraction of stages. But how much complementarity is actually warranted for CSR investments along the value chain?

Well-mediatised but rare events with strong impact on demand like the collapse of the Rana Plaza factory in 2013 or the Nike sweatshop campaign seem to suggest that extreme levels of complementarity may be appropriate when a single “bad apple” in the production chain jeopardizes total sales. Our aim, however, is not to model the effect of such events on the individual firms involved. Our modeling rather concerns the impact of a general awareness of and demand for ethical production (which may be spurred by such exceptional events). With CSR being defined as investments above and beyond local legal requirements, we deem it plausible that a level of zero in some stages does not have devastating effects on demand.

However, we would like to maintain some level of complementarity between CSR at different production stages. Technically, this implies that we should think of α as being relatively small, i.e., closer to zero than to unity. We will see below that the value of α *relative* to the value of ρ matters in our model. The latter also lies between zero and one (see Footnote 15) and represents the ease with which a consumer can substitute one ethically differentiated variety for another with the identical level of ethical quality. Given that the only source of horizontal differentiation lies in the different ethical narratives of otherwise identical varieties, and given our argument above that α should be relatively close to zero, we focus our analysis on the case where $\alpha < \rho$.¹⁶

5.2.2.2 Production of Physical Output

For each intermediate j , there is a large number of specialized potential suppliers in South. The firm picks one supplier for each stage.¹⁷ For simplicity, we assume that all stages are identical across varieties.

Aghion et al. (2020). In our benchmark model, we have $\nu = 1$. The smaller ν , the higher values of $\rho > 1/2$ are possible up to the usual upper bound of one. To keep the model as simple as possible, we choose to restrict the range of possible values for ρ rather than to introduce an additional parameter.

¹⁶In Antràs and Chor (2013), the parameter α governs the substitutability between quality-adjusted input quantities of the different suppliers (production stages). Clearly, here it would be much more difficult to argue why this - technical - substitutability should be larger or smaller than ρ . Antràs and Chor (2013) thus consider both cases (sequential complements and sequential substitutes) and build their empirical analysis on this distinction. We refrain from doing so for two reasons. First, we have argued above why we think $\alpha < \rho$ is appropriate and second, to our knowledge, there has yet to be found a dataset and a method to empirically determine the value of alpha (the substitutability of CSR levels across suppliers) for different sectors.

¹⁷In Footnote 27, we show that it is optimal for a firm serving caring consumers to pick only one supplier for each stage.

Physical production along the value chain takes place according to a Leontief production function. This implies that the production of one unit of final output requires a fixed quantity of each intermediate input j . For simplicity, we assume symmetry across stages and normalize all the Leontief coefficients to 1. Physical output of variety ω is then given by

$$q(\omega) = \min_j \{I(j) x(j)\} \quad (5.4)$$

where the minimum is taken over all $j \in [0, 1]$ and $x(j)$ is the quantity of input j used in the production process. The indicator function $I(j)$ equals one if the input is provided at the appropriate stage and zero otherwise. This indicator function introduces sequentiality into the production process.¹⁸

It follows that the quantity of the input the firm sources at stage j is given by $x(j) = q(\omega)$.¹⁹ For simplicity, we assume identical marginal production costs c_x for all stages. The total production cost of one unit of the final output is therefore given by:

$$\int_0^1 c_x dj = c_x. \quad (5.5)$$

With this Leontief production function, we deviate from Antràs and Chor (2013) who assume gross substitutability across stages. Our choice of production technology is in line, however, with other papers in the literature on the internationalization of production like Grossman and Rossi-Hansberg (2008), Costinot et al. (2013), or Grossman and Helpman (2020). In our view, assuming that inputs along a value chain are complements rather than substitutes appears plausible. Consider, for example, the production of a car. Four wheels and one steering wheel are needed for an operational car and there is no way to substitute one type of wheel for another. Our choice is supported by a recent paper by Boehm et al. (2019) who find a level of complementarity close to Leontief between imported and domestic inputs for Japanese affiliates in the U.S.²⁰

5.2.3 Sourcing with Sequential Production

We now describe the options of the firm to source inputs from independent suppliers in a sequential production process with incomplete contracts. We specify demand by caring as well as non-caring consumers, discuss the hold-up problem resulting from incomplete contracts and specify the bargaining process between the firm and its suppliers.

5.2.3.1 Relational vs. Anonymous Sourcing

Firms can choose to source any input j either from a matched supplier or from the input market. While CSR investments of a matched supplier contribute to the perceived ethical quality, $\varepsilon(\omega)$, an input sourced from the input market does not. We can think of this as an anonymous market where the input

¹⁸This may seem like a very fragile production process: any violation of the appropriate ordering or any failure of a supplier to contribute its intermediate lead to zero output. We assume, however, that the firm can always buy any input j on the input market, where a generic (zero-CSR) version of each input is readily available at marginal production costs of suppliers. We describe this input market in detail in Section 5.2.3.1. This implies that the firm can always assure the right sequencing and the required quantity for each input.

¹⁹We postpone the detailed discussion of why this is the case to Footnote 24, as the argument relies on the effects of the input market introduced below.

²⁰The choice of perfect complementarity has the additional advantage that it allows us to study the decision of CSR investments in ethical quality independently of the decision on production quantities. Without perfect complementarity, our model would imply trade off between quantity and ethical quality in the eyes of caring consumers, an implication we neither find realistic nor appealing.

cannot be linked to a specific supplier in a way that would affect the perceived ethical quality of the final product. This can be the case when the identity of the producer(s) and/or information about production conditions are lost or not verifiable.²¹ The large number of potential suppliers for each input j in South stands ready to produce any quantity of inputs for the world market for a price covering their physical production costs.²²

5.2.3.2 Demand and Firm Revenue

Let us first consider a firm serving non-caring consumers. These firms do not have to incur a fixed cost and operate under perfect competition with a market price $p_h = c_x$, implying zero profits. They can either source the inputs for all stages from the input market or source input j from a matched supplier. The indifference of non-caring consumers to CSR investments implies that the firm has no reason to pay a price above the marginal production cost for each input along the value chain. Competing with suppliers on the input market, also a matched supplier will not invest in costly CSR. In the eyes of non-caring consumers, output of different firms is perfectly substitutable, they will therefore only buy from firms with the lowest prices, i.e., firms with zero CSR along the value chain. At the same time, the output of firms serving non-caring consumers is of no value at all to caring consumers, as they derive no utility from consumption when $\varepsilon(\omega) = 0$.

Let us now turn to a firm serving caring consumers. The firm must pay an initial fixed cost f of marketing its output to caring consumers.²³ A positive value of perceived ethical quality $\varepsilon(\omega) > 0$ then provides vertical product differentiation and allows the firm to charge a price above marginal cost - a price at which non-caring consumers are unwilling to buy. It directly follows that firms specialize in serving either caring or non-caring consumers by opting for imperfect competition with ‘ethical differentiation’ or perfect competition. We will get back to this decision when analyzing the industry equilibrium of our model in Section 5.2.5.1.

Maximizing utility of caring consumers in Equation (5.1) subject to the budget constraint gives inverse demand as

$$p(\omega) = q(\omega)^{-(1-\rho)} \varepsilon(\omega)^\rho A^{1-\rho} \quad (5.6)$$

where $p(\omega)$ is the price of one physical unit of variety ω and $A = E/P^{-\rho/(1-\rho)}$ is a demand shifter consisting of total expenditure E as well as the price index P , which are both taken as given by the firm.

Firm revenue is $r(\omega) = p(\omega)q(\omega)$. Inserting (5.6) for $p(\omega)$ gives $r(\omega) = \varepsilon(\omega)^\rho q(\omega)^\rho A^{1-\rho}$. Combined with (5.3), this implies

$$r(\omega) = q(\omega)^\rho A^{1-\rho} \left(\int_0^1 s(j)^\alpha dj \right)^{\rho/\alpha}. \quad (5.7)$$

Revenues depend positively on total scale of production, $q(\omega)$, the general level of demand, summarized

²¹Fair trade coffee beans nicely illustrate the point. There is a market for Fair Trade coffee beans and a market for ‘regular’ coffee beans. Due to limited demand and over-production of the Fair Trade farmers, some of the Fair Trade coffee beans are not sold under the Fair Trade label, but are sold as ‘regular’ coffee beans on the world market. As the production conditions cannot be inferred from the coffee bean itself, the information is lost and no buyer can use the Fair Trade label to advertise its final product - even though the coffee beans may have been produced respecting the Fair Trade standards. See, for example, Dragusanu et al. (2014) and de Janvry et al. (2015). Related to our modeling of ethical quality differentiation through CSR, Dragusanu et al. (2022) show that in the coffee market fair trade certification is linked to higher sales.

²²In recent work, Cajal-Grossi et al. (2020) find patterns in the Bangladeshi garments sector that are consistent with our modeling: suppliers obtain higher prices when selling to relational buyers than when selling to spot buyers.

²³We think of these costs as expenses informing consumers about the product and establishing credibility for the ethical content of its production process.

in A , as well as the perceived ethical quality, which is composed of the CSR levels all along the value chain.

5.2.3.3 Hold-Up and Bargaining

We maintain the assumption on incomplete contracts for the physical input $x(m)$ from the Antràs literature. However, due to our assumption of a Leontief production technology from equation (5.4), incomplete contracts do not lead to underinvestment in quantities and the outcome is therefore observationally equivalent to a setting of complete contracts.²⁴ Grossman and Helpman (2020) also use a Leontief technology and make a related argument.

Because the CSR investment makes the input produced by a supplier at some stage m relationship-specific, the firm and its supplier face a standard hold-up problem and the need to share the surplus generated by the CSR investment. In the characterization of the interaction between the firm and the supplier, we closely follow the setting in Antràs and Chor (2013). The firm only pays the supplier after production has taken place, i.e., when the physical production costs are sunk, the CSR investment is sunk and the firm observes the implemented CSR level.

As outlined above, the firm can buy the necessary amount of input m on the input market in case the supplier does not deliver. By the same token, the supplier can sell the input on the input market if no agreement with the firm is reached. This implies that at the bargaining stage the supplier m has an outside option of $c_x x(m)$ and the firm has an outside option of $-c_x x(m)$. It is a standard result that in the equilibrium of the Nash bargaining game each party receives its outside option and the remaining surplus is split between the two parties according to their bargaining power, which we denote by β for the firm and $1 - \beta$ for the supplier. Given the symmetric outside options, this implies that at each stage the firm pays the supplier its production costs $c_x x(m)$ as well as a fraction $1 - \beta$ of the remaining surplus. We follow Grossman and Hart (1986), who assume a fifty-fifty split of the surplus, and Antràs (2003), who assumes that $\beta > 1/2$, and assume $\beta \geq 1/2$.

5.2.3.4 Incremental Contribution at Stage m

As the firm is in full control of the sequencing of the production stages, we have $I(j) = 1 \forall j < m$ when bargaining at stage m takes place. Recall that the firm can always complete the remaining production stages $j \in [m, 1]$ with inputs purchased on the input market, which do not add to the perceived ethical quality of the final product. At stage m , the firm can therefore be *certain* to obtain *at least* the following revenues:

$$r(m) = q(\omega)^\rho A^{1-\rho} \left(\int_0^m s(j)^\alpha dj \right)^{\rho/\alpha}. \quad (5.8)$$

These are the revenues the firm has secured up to stage m when negotiating with the supplier. The incremental contribution of the supplier at stage m can then be computed using Leibniz' rule:

$$r'(m) = \frac{\partial r(m)}{\partial m} = \frac{\rho}{\alpha} A^{\frac{\alpha(1-\rho)}{\rho}} q(\omega)^\alpha s(m)^\alpha r(m)^{\frac{\rho-\alpha}{\rho}}. \quad (5.9)$$

The incremental contribution to revenue generated at stage m increases in total demand, as reflected

²⁴ Concerning the optimal input quantity $x(m)$ of a supplier under incomplete contracts and a Leontief production function, consider the following. For any given order size $q(\omega)$ issued by the firm to all its suppliers, a single supplier can either produce more than, less than, or exactly $q(\omega)$. Producing more would be inefficient, as the firm would not seek to buy it. With the CSR investment acting like a fixed cost for the supplier, and the surplus of the match, i.e., the compensation for the supplier, increases in $x(m)$ until $x(m) = q(\omega)$ is reached. This implies that the supplier maximizes its compensation for $x(m) = q(\omega)$, which is strictly preferred to zero CSR, which delivers zero profits for any $x(m)$.

by A , in the total scale of production, $q(\omega)$, and in the consumer valuation of the implemented standard, $s(m)$ as well as in all previous CSR investments included in $r(m)$. The assumption that $\alpha \in (0, \rho)$ assures that the latter effect is positive.²⁵ We follow the baseline model in Antràs and Chor (2013) in assuming that this incremental contribution of the supplier to the secured revenues is the surplus of the match and therefore also the surplus bargained over.²⁶

5.2.3.5 Bargaining along the Value Chain

Based on the bargaining between the firm and its supplier at stage m , we can now specify the game played by the firm and the continuum of suppliers along the value chain. Initially, the firm selects the physical output $q(\omega)$ it seeks to produce. The firm then selects one supplier for each stage j from a large pool of potential suppliers. Suppliers that were not selected by a firm stand ready to sell input j on the input market at any price larger or equal the production cost c_x . After this, production takes place sequentially starting at $j = 0$ and the firm assures that the optimal sequence of production is respected. Based on the information contained in equation (5.8), the supplier chooses its CSR investment $c_s s(m)$. At the end of the stage, firm and supplier bargain over the surplus of the match. The firm compensates the supplier for the physical production costs and pays it a fraction $(1 - \beta)$ of its incremental contribution to total revenues, $r'(m)$, given by (5.9). After stage $j = 1$ is completed, the final consumption good is produced by the firm and sold to consumers generating total revenues given by equation (5.7).

5.2.4 CSR Investments

We now turn to the CSR investments of suppliers. First, we consider an individual supplier and then the entire chain of suppliers taking aggregate variables as given. We analyze the determinants of CSR investments at different production stages in this partial equilibrium context. In Section 5.2.5 we derive the industry equilibrium of our model and analyze the equilibrium determinants of CSR along the value chain.

The supplier at stage m of the production process knows that it will be compensated for the production cost either by the firm or by selling on the input market. Production costs therefore do not enter the supplier's problem, which is given by:

$$\max_{s(m)} \pi_s(m) = (1 - \beta)r'(m) - c_s s(m). \quad (5.10)$$

This leads to the following expression for the production standard at stage m :

$$s(m) = \left[(1 - \beta) \frac{\rho}{c_s} A^{\frac{\alpha(1-\rho)}{\rho}} q(\omega)^\alpha \right]^{\frac{1}{1-\alpha}} r(m)^{\frac{\rho-\alpha}{\rho(1-\alpha)}}. \quad (5.11)$$

Quite intuitively, the optimal level of CSR at stage m is decreasing in the marginal cost of CSR c_s , increasing in the supplier's bargaining power, $1 - \beta$, and increasing in the order size $q(\omega)$ placed by the firm. Combined with equation (5.8), the above equation links the optimal CSR level at stage m to all

²⁵In this context, the assumption of $\alpha \in (0, \rho)$ merits some more discussion, as it relates to the key mechanism in Antràs and Chor (2013). Their central results stem from distinguishing the cases of $\alpha < \rho$ (sequential complements) and $\alpha > \rho$ (sequential substitutes), where α shapes the substitutability of input quantities across production stages. As outlined in Section 5.2.2.1, it seems to be an eminently plausible assumption that substitutability of CSR levels across production stages is quite low so that we consider the case of sequential complementarity in our baseline setting.

²⁶This implies that supplier m 's indirect contribution to final revenue, which goes through the effect of supplier m 's investment on the investment decisions of more downstream suppliers, does not enter the bargaining. This simplifying assumption assures that the sequential bargaining of the firm with a continuum of suppliers remains tractable. Antràs and Chor (2013) show that this assumption can be relaxed and study an extension of the model that delivers the identical results on the supplier's investments as in the baseline model.

previous CSR levels. Under the maintained assumption discussed in Section 5.2.2.1 that $\alpha \in (0, \rho)$, CSR investment at stage m is increasing in previous CSR levels. This allows us to state the following lemma:

Lemma 1 *With $\alpha \in (0, \rho)$, CSR investments along the value chain are sequential complements, i.e., higher levels in previous stages lead to a higher optimal level of CSR in stage m .*

Proof: *In the text.*

When the incentives for CSR investment of suppliers depend on previous investments by other suppliers, the position in the value chain relative to other suppliers can become a crucial determinant of CSR investment. We therefore now turn to the sequence of CSR investments along the complete value chain. Combining equation (5.11) with equation (5.9), we obtain

$$r'(m) = \frac{1}{\alpha} \left(\frac{1-\beta}{c_s} \right)^{\frac{\alpha}{1-\alpha}} \left[\rho A^{\frac{\alpha(1-\rho)}{\rho}} q(\omega)^\alpha \right]^{\frac{1}{1-\alpha}} r(m)^{\frac{\rho-\alpha}{\rho(1-\alpha)}}. \quad (5.12)$$

Using the initial condition $r(0) = 0$, solving this differential equation delivers

$$r(m) = \left(\frac{1-\rho}{1-\alpha} \right)^{\frac{\rho(1-\alpha)}{\alpha(1-\rho)}} \left(\frac{1-\beta}{c_s} \rho \right)^{\frac{\rho}{1-\rho}} A q(\omega)^{\frac{\rho}{1-\rho}} m^{\frac{\rho(1-\alpha)}{\alpha(1-\rho)}}. \quad (5.13)$$

We can now plug this into equation (5.11), which delivers CSR investments at stage m as

$$s(m) = \left(\frac{1-\rho}{1-\alpha} \right)^{\frac{\rho-\alpha}{\alpha(1-\rho)}} \left(\frac{1-\beta}{c_s} \rho \right)^{\frac{1}{1-\rho}} A q(\omega)^{\frac{\rho}{1-\rho}} m^{\frac{\rho-\alpha}{\alpha(1-\rho)}}. \quad (5.14)$$

This expression for CSR investments at stage m accounts for CSR investments in all previous stages, which affect the optimal choice at stage m according to Lemma 1. Equation (5.14) shows that the standard implemented at stage m depends on the size of the order $q(\omega)$ placed by the firm, which we determine next.²⁷

Total physical output $q(\omega)$ is chosen by the firm in the first stage of the game. The firm knows that it will either have to purchase inputs on the input market or has to compensate its suppliers for their production costs. In either case, costs are given by $\int_0^1 c_x q(\omega) dj = c_x q(\omega)$. The problem of the firm is therefore given by:

$$\max_{q(\omega)} \pi_F(\omega) = \beta r(\omega) - c_x q(\omega) - f. \quad (5.15)$$

Based on equation (5.13) evaluated at $m = 1$, we can write total revenue as

$$r(\omega) = \left(\frac{1-\rho}{1-\alpha} \right)^{\frac{\rho(1-\alpha)}{\alpha(1-\rho)}} \left(\frac{1-\beta}{c_s} \rho \right)^{\frac{\rho}{1-\rho}} A q(\omega)^{\frac{\rho}{1-\rho}}. \quad (5.16)$$

Differentiating $\pi_F(\omega)$ with respect to $q(\omega)$ and setting the derivative equal to zero gives the optimal quantity $q(\omega)$ as

$$q(\omega) = \left(\frac{1-\rho}{1-\alpha} \right)^{\frac{\rho(1-\alpha)}{\alpha(1-2\rho)}} \left(\frac{1-\beta}{c_s} \rho \right)^{\frac{\rho}{1-2\rho}} \left(\frac{\rho}{1-\rho} \frac{\beta}{c_x} A \right)^{\frac{1-\rho}{1-2\rho}}. \quad (5.17)$$

²⁷Note that the fact that $s(m)$ increases in the size of the order $q(\omega)$ placed by the firm implies that the firm has an incentive to order the entire quantity of input m from one single supplier, as this maximizes the level of the standard under which production takes place and therefore also maximizes the level of perceived ethical quality of the final product.

We can combine equations (5.14) and (5.17) and use the definition of $A = EP^{\frac{\rho}{1-\rho}}$ to get the optimal CSR investment at stage m ,

$$s(m) = \left(\frac{1-\rho}{1-\alpha} \right)^{\frac{\rho-\alpha(1-\rho)}{\alpha(1-2\rho)}} \left(\frac{1-\beta}{c_s} \rho E \right)^{\frac{1-\rho}{1-2\rho}} \left(\frac{\rho}{1-\rho} \frac{\beta}{c_x} P \right)^{\frac{\rho}{1-2\rho}} m^{\frac{\rho-\alpha}{\alpha(1-\rho)}}. \quad (5.18)$$

We can now state the following lemma:

Lemma 2 *Equation (5.18) characterizes how suppliers along a firm's value chain optimally choose their CSR levels taking aggregate variables as given (partial equilibrium). The production standard is higher in more downstream stages, i.e., suppliers that are closer to the final consumer invest more in CSR. With the price index P taken as given, CSR investments also increase in the total expenditure on ethically differentiated goods E .*

Proof: *This follows directly from equation (5.18) and $\rho < 1/2$.*

Lemma 2 shows that the supplier's CSR investment increases in m , i.e., CSR is higher in more downstream stages. The result reflects the fact that CSR investments are sequential complements along the value chain, as pointed out in Lemma 1. In addition, the overall level of CSR investment across all stages is increasing in aggregate expenditure on ethically differentiated goods. We will see below that E disappears from the equation when we solve for the industry equilibrium of our model. There, a supplier's position in the value chain will emerge as the key determinant of its CSR expenditures in our model.

5.2.5 Equilibrium CSR

We now derive the industry equilibrium of the model with free entry of final goods producers. This allows us to analyze the equilibrium determinants of CSR investments at the different stages of production.

5.2.5.1 Industry Equilibrium

To solve for the industry equilibrium, we assume free entry and final good producers with homogeneous levels of productivity normalized to 1 so that it must hold that $\pi_F(\omega) = 0 \forall \omega$.

Setting equation (5.15) equal to zero, plugging in the optimal $q(\omega)$ from equation (5.17), and using the fact that $A = EP^{\frac{\rho}{1-\rho}}$ gives an expression for the price index P as

$$P = \left(\frac{1-\alpha}{1-\rho} \right)^{\frac{\rho-\alpha}{\alpha\rho}} \left(\frac{1-\alpha}{\beta E} \right)^{\frac{1-\rho}{\rho}} \frac{c_s c_x}{\rho^2 (1-\beta)} \left(\frac{f}{1-2\rho} \right)^{\frac{1-2\rho}{\rho}}. \quad (5.19)$$

Next, we solve for the equilibrium number of firms using the optimal pricing rule and the definition of the ideal price index from demand.²⁸ From this, we get a second expression for the price index as a function of the number of firms n as

$$P = n^{-\frac{1-\rho}{\rho}} \frac{c_x c_s}{\rho^2 (1-\beta)} \frac{1-2\rho}{f} \left(\frac{1-\alpha}{1-\rho} \right)^{\frac{1-\alpha}{\alpha}}. \quad (5.20)$$

Combining the two results for the price index, one from free entry, equation (5.19), and one from demand, equation (5.20), gives the equilibrium number of firms as

$$n = \frac{\beta E}{1-\rho} \frac{1-2\rho}{f}. \quad (5.21)$$

²⁸Details of the derivations are provided in Appendix 5.5.1.

Combining equation (5.19) with equation (5.17) on the one hand, and the definition of $A = EP^{\frac{\rho}{1-\rho}}$ on the other hand, yields expressions for order size $q(\omega)$ and the market size parameter A in industry equilibrium as

$$q(\omega) = \frac{\rho}{c_x} \frac{f}{1-2\rho} \quad (5.22)$$

and

$$A = \left(\frac{1-\alpha}{1-\rho} \right)^{\frac{\rho-\alpha}{\alpha(1-\rho)}} \frac{1-\alpha}{\beta} \left[\frac{c_s c_x}{\rho^2 (1-\beta)} \right]^{\frac{\rho}{1-\rho}} \left(\frac{f}{1-2\rho} \right)^{\frac{1-2\rho}{1-\rho}}. \quad (5.23)$$

This allows us to state the following lemma:

Lemma 3 *In industry equilibrium with free entry in the final goods sector, final goods producer size $q(\omega)$ and the equilibrium market size parameter A are both independent of exogenous aggregate expenditure E .*

Proof: *Follows directly from equations (5.22) and (5.23).*

Market and firm size are both independent of the aggregate level of expenditure E in the economy. The reason is that in our setup of free entry with homogeneous final good producers, any increase in aggregate spending will be fully compensated by additional entry into the final goods sector.

5.2.5.2 Equilibrium CSR along the Global Value Chain

Combining equations (5.18) and (5.19), the CSR level implemented at stage m can be written as

$$s(m) = \frac{f}{1-2\rho} \frac{(1-\alpha)\rho}{c_s} \frac{1-\beta}{\beta} m^{\frac{\rho-\alpha}{\alpha(1-\rho)}}. \quad (5.24)$$

It only depends on parameters and the production stage m . We can now state the following proposition:

Proposition 1 – Equilibrium CSR along the Global Value Chain. *With CSR investments across production stages being sequential complements, CSR expenditures $s(m)$ in industry equilibrium are increasing along the value chain from upstream to downstream stages.*

Proof: *This follows directly from equation (5.24).*

This constitutes the main theoretical result of our paper: equilibrium CSR levels increase along the value chain as suppliers get closer to the final consumer. The result is driven by the fact that investments in CSR are sequential complements, as established in Lemma 1: the larger CSR investments at a given stage m , the higher the incentive for more downstream suppliers to invest more. Comparison of the partial equilibrium expression (5.18) and the equilibrium expression in (5.24) shows that the increasing profile, our central finding, persists in industry equilibrium. The effect of total expenditure E established in Lemma 2, however, does not survive endogenizing the price index P . We argue below that we use this difference to draw the line between the core testable implication of our model, which holds in industry equilibrium, and variables we merely control for in the empirical analysis, as they play a role in the partial equilibrium analysis only.

Comparison of Proposition 1 to the outcome under complete contracts (see Appendix 5.5.2) shows that the increasing profile of CSR results from the setting of incomplete contracts. We argued above that CSR investments are in many cases observable but non-verifiable (Hart and Moore, 1999). Our model therefore hints at a general problem that may well be a typical feature of CSR along global value chains: when CSR investments are sequential complements (the case for which we argued in Section 5.2.2.1), the early stages of the production process are the ones that are crucial for the choices along the entire

value chain; at the same time, these are the stages with the lowest CSR investments. This implies that for both headquarters and policy makers who seek to increase overall CSR levels along the value chain, the upstream stages of production are the most important ones to target.

5.2.6 Discussion and Link to the Data

Before we turn to the empirical analysis, we pause to first discuss how we link our theoretical results to the data. We then place our analysis in the context of the literature on incomplete contracts in international economics and explain why our theory-informed empirical analysis closes a gap in this literature.

5.2.6.1 Testable Implications: Partial vs. Industry Equilibrium

As pointed out above, comparison of the partial equilibrium expression for CSR (5.18) and its industry equilibrium counterpart (5.24) shows that the central prediction of our theory – the increasing profile of CSR along the value chain – also holds in industry equilibrium. We bring this prediction to the data in Section 5.3, where we also provide a detailed description of the data. At this stage, simply note that we use Indian firm-level data together with input-output tables to compute a firm-level measure of upstreamness. Moreover, we observe CSR investments at the firm level. This allows us to investigate the negative relationship between upstreamness and CSR investments established in Proposition 1. If we had ended the theoretical analysis with the partial equilibrium expression for CSR investments in equation (5.18), we could have deduced additional testable implications from the theory. Specifically, taking the price index P as given, Lemma 2 states that the CSR investments by the supplier at stage m of the production process increase in total expenditures on ethically differentiated goods, E .

One could test this implication from partial equilibrium empirically by taking, e.g., the share of sales going to OECD countries as a proxy for being exposed to stronger demand for ethical quality. Proposition 1, however, shows that when the equilibrium price index is accounted for, the effect of E vanishes. This is an implication of the simple Krugman (1980) structure of our modeling of the ethically differentiated homogeneous final good producers, which leads them to having a constant equilibrium size. Adjustments to changes in aggregate variables are exclusively driven by adjustments in the number of firms (see equations (5.21) and (5.22)). As the impact of demand for ethical products does not survive the computation of the industry equilibrium, we do not consider it a core testable implication of our model. The partial equilibrium analysis nevertheless points to its relevance, and we therefore include in our regressions a proxy for OECD export exposure as a control variable.

5.2.6.2 A Direct Measure of the Non-Contractible Variable

As indicated above, our data allow us to take a very direct approach to linking our model to the data. In our opinion, this approach fills a gap in the empirical literature on the role of incomplete contracts in international economics. The literature is surveyed in Antràs and Yeaple (2014) and Antràs (2016), with Alfaro et al. (2019) being a recent example. The empirical studies are grounded in theoretical models, where incomplete contracts lead to underinvestment in a relationship-specific non-contractible variable (typically quality-adjusted inputs). In our model, this non-contractible variable is CSR investment, which has some similarities with the quality dimension in the mentioned literature. It goes without saying that such non-contractible variables are difficult to measure. The literature therefore typically resorts to the observable organization of production as a dependent variable, which – according to the theory – is driven by the unobservable non-contractible variable. Nunn (2007) sheds empirical light on this theoretical mechanism showing that relationship-specificity shapes the patterns of international trade. Based on Nunn (2007), Nunn and Treffer (2008) construct a country and industry specific measure

of contractual completeness. They find that improved contracting of the inputs provided by the supplier favors integration over outsourcing. Our analysis adds an additional and complementary dimension: To our knowledge, ours is the first paper to use a direct measure of the non-contractible variable. This becomes possible as we shift the attention from some technical, but by construction externally unobservable, product or service characteristic to CSR investments, for which we do have a firm-level measure in our data. We can therefore directly study the effect – in our case of a supplier’s value chain position – on the non-contractible variable without recurring to the organization of production as a substitute observable outcome for the unobservable (under)investment decision.²⁹

5.3 GVC Position and CSR in India

In this section, we take the model to the data by testing whether CSR spending is larger when firms are positioned more downstream in global value chains. We begin with the description of the data.

5.3.1 Data Description

For our analysis, we combine the World Input-Output Database (WIOD, Timmer et al., 2015) with the Prowess database.³⁰ Our sample covers the years 2000 to 2013. The Prowess database contains a wide range of Indian firm-level information. Its coverage of the Indian economy is comprehensive, with total production of all companies in Prowess accounting for more than 80% of India’s GDP (Bos and Vannoorenberghe, 2018). The data are collected by the Centre for Monitoring Indian Economy (CMIE), which mainly sources information from annual reports of firms, stock exchanges and regulators. India is particularly well-suited to bring the theoretical predictions of our model to the data.³¹

In our theory, CSR is any action by a supplier that leads to an increase in the perceived ethical quality of the final product. This can be any action that makes the supplier appear more ethical in the eyes of consumers. We therefore use details on firms’ spending on staff welfare and expenses for the benefit of society or the community in general as our measure of a firm’s CSR activities, our dependent variable. It is a unique feature of the data, and especially rare in an emerging economy context, that we can observe this information at the firm level. We describe the variable in more detail in Section 5.3.2.1.

Moreover, the data include detailed information on general firm characteristics such as annual sales, export activity, ownership, input sourcing, age and the product mix. The latter is key for our empirical strategy.³² We exploit differences in the product mix across firms as well as within firms over time to construct a firm-specific measure of the global value chain position. To do so, we combine the Prowess data with industry-level information from WIOD. In a first step, we follow Antràs et al. (2012) and Antràs and Chor (2018) and use WIOD to construct a time-varying measure of Indian industries’ *upstreamness*.

²⁹We do acknowledge that the analysis of the determinants of the integration vs. outsourcing decision of the firm is an important endeavor in its own right. Here, we simply want to highlight that our approach allows us to investigate the non-contractible variable directly and thereby closes a gap in the previous literature.

³⁰We use the Prowess vintage of December 2017. Data were downloaded from <https://prowessdx.cmie.com> on February 1, 2018. The WIOD release 2016 was downloaded from <http://wiod.org/home>. Data were downloaded on July 22, 2019.

³¹First, the reduction in trade barriers following India’s accession to the WTO in 1995 substantially increased India’s integration into GVCs. Second, compared to most developed countries, firms in India are much less constrained by labor and environmental standards leaving ample room for voluntary CSR investments. Finally, related to our assumption of incomplete contracts, the congested court system (Boehm and Oberfield, 2020) amplifies the problem that contracts between the supplier and the headquarter are observable but not verifiable (Hart and Moore, 1999).

³²Goldberg et al. (2010b) emphasize that it is a rare feature of the Prowess database that it captures annual changes in the product mix at the firm level. This feature stems from the Indian 1956 Companies Act requiring firms to disclose product-level information on capacities, production and sales in their annual reports. Several previous studies have used this information, e.g., Goldberg et al. (2010a), Goldberg et al. (2010b), De Loecker et al. (2016), Barrows and Ollivier (2018), Bos and Vannoorenberghe (2018) and Barrows and Ollivier (2021).

Linking WIOD industries to the firms’ products from Prowess, we use the product-level sales shares as weights in the calculation of an average, firm-specific upstreamness, our measure of a firm’s value chain position. We describe the calculation of our main independent variable in more detail in Section 5.3.2.2.

Notably, multi-product firms account for 47% of Indian manufacturing firms and 80% of manufacturing output (Goldberg et al., 2010b, p.1043). Therefore, a key feature of our approach is that even for firms within the same main industry, measured GVC positions may differ across firms, either because of differences in the product mix or because of differences in the sales weights of identical product mixes. Our measure also varies over time and within firms if a firm’s product sales weights change or if it adds or drops products. In addition, a firm’s value chain position may change over a longer horizon if the position of its products changes.

Section 135 of the 2013 Indian Companies Act obliges firms above a certain turnover and profitability threshold to spend 2% of their average net profits on CSR. Compliance with the law changes the CSR decision of a firm and might also change its reporting behavior.³³ To avoid such a discontinuity in their CSR spending, we limit the analysis to the period between 2000 and 2013, although our data are available up to 2014.³⁴ In the next section, we describe our key variables of interest, CSR spending and a firm’s GVC position, in more detail.

5.3.2 Measuring CSR Spending along GVCs

A complex set of motives can drive a firm’s strategy on CSR spending (Bénabou and Tirole, 2010; Crifo and Forget, 2015). Crifo and Forget (2015) describe a firm’s CSR decision as a response to market imperfections with the aim of satisfying social preferences of at least one stakeholder. In the context of GVCs, satisfying these social preferences becomes even more complex as firms face not just domestic but also foreign stakeholder demands (Newman et al., 2018). Consumers in developed countries increasingly demand that minimum standards for working conditions and environmental aspects of production are observed also at production sites abroad. Before we focus on the empirical specification, we explain our measure of CSR spending.

5.3.2.1 Measuring a Firm’s CSR Spending

There is no general agreement about the definition of CSR nor a common way of quantifying CSR spending (Crifo and Forget, 2015; Newman et al., 2020). Shirodkar et al. (2018) claim that in the context of developing and emerging countries, CSR primarily refers to the commitment to behave ethically and to contribute to economic development. McWilliams and Siegel (2001, p.117) define CSR more strictly as “actions that appear to further some social good, beyond the interests of the firm and that which is required by law”. In this paper, we follow this concept and a large literature by defining our dependent variable as social spending beyond what is required by law (Bénabou and Tirole, 2010; Crifo and Forget, 2015; Newman et al., 2018, 2020).

We argue that this approach is especially well-suited in the context of GVC integration of firms originating from developing or emerging countries because these firms are operating in a relatively lax social and environmental regulatory setting. Facing lenient domestic regulation, firms respond to market failure with higher CSR spending to satisfy stakeholder demands (Bénabou and Tirole, 2010; Crifo and Forget, 2015). In the context of GVC integration, the CSR decision of firms located in developing countries is determined by relatively higher demand for CSR by *foreign* stakeholders (Newman et al., 2018).

³³See Dharmapala and Khanna (2018) for more details on the legislation and an evaluation of the effects on firm’s CSR activities.

³⁴To control for potential anticipation effects, we carry out a robustness test (available upon request) where we exclude the years 2011 to 2013. We find that our results are unaffected.

Our data allow us to directly observe monetary CSR spending on own staff welfare and expenses for the benefit of the society or the community. We use this information to measure what we call *production standard* or *CSR investment* in the theoretical model. *Staff welfare spending* refers to various amenities that are made available to the employees for their general welfare and go beyond regular compensation in the form of salaries. Staff welfare spending includes free or subsidized medical treatment, transportation facilities, recreation facilities, staff food, and canteen expenses. These aspects all cover labor welfare, which is the predominant component of CSR spending in emerging economies (Newman et al., 2018). *Society or community spending* refers to expenses on building or maintaining public parks, garden maintenance, building temples, constructing roads or contributing to social occasions, etc. These community-related expenses closely refer to the catalog of community-related CSR activities applied by Newman et al. (2018) and Newman et al. (2020).³⁵

Our ability to observe the money amount of CSR spending allows us to investigate the continuous relationship between CSR spending and a firm’s position in GVCs. Accordingly, we can directly exploit variation in the level of CSR spending across firms and within a firm over time. We argue that our focus on observable data of the monetary expenses related to CSR, but not labeled CSR, substantially reduces a possible bias due to self-reporting of firms as discussed in Newman et al. (2020).

5.3.2.2 Measuring a Firm’s Value Chain Position

We now turn to the key explanatory variable of interest: a firm’s GVC position. Our model predicts that a firm’s CSR spending depends crucially on its position in the value chain. Without recurring to a theoretical model, Newman et al. (2018) control for the role of the value chain position by using a time-invariant firm fixed effect. Our data allow us to not only control for a possible impact of the value chain position of CSR but to estimate the effect. To do so, we calculate a time-varying and firm-specific measure of a firm’s position in GVCs based on a combination of value chain information of industries from the World Input-Output Database and the Prowess information on product-level sales of firms.

In a first step, we calculate Indian industries’ position in GVCs based on contributions by Antràs et al. (2012) and Antràs and Chor (2018). They show how World Input-Output Tables can be used to calculate an industry’s *upstreamness*, measuring the distance of an industry’s sales from final consumption. In line with this approach, we start by computing upstreamness U_k^v of industry v in country k (India) by computing

$$U_k^v = 1 \frac{F_k^v}{Y_k^v} + 2 \frac{\sum_{w=1}^W \sum_{l=1}^L a_{kl}^{vw} F_l^w}{Y_k^v} + 3 \frac{\sum_{w=1}^W \sum_{l=1}^L \sum_{x=1}^W \sum_{m=1}^L a_{kl}^{vw} a_{lm}^{wx} F_m^x}{Y_k^v} + \dots, \quad (5.25)$$

where F_k^v/Y_k^v is the share of global final consumption in industry v ’s gross output in country k . The following terms capture the proximity to final consumption of industry v in country k through its sales in intermediates. For instance, the second summand includes the share of output from industry v in country k , which is consumed by industry w in country l and sold to final consumers, multiplied by a_{kl}^{vw} , which measures the dollar amount of industry v ’s output in country k needed to produce one dollar worth of industry w ’s output in country l .

The upstreamness of an industry is the weighted average of the number of stages that separate the typical unit of output in industry v from final consumers. The weighting scheme gives higher weight to

³⁵ Another important CSR component is spending related to environmental issues. Although we observe expenses on environmental causes in our data, we do not include this dimension in our main specification. The reason is that we cannot be sure that these expenses are truly voluntary. This variable could also capture, e.g., compulsory investment in environmentally friendly technologies required by law. The results for the extended CSR measure including environmental expenses stay robust and are available upon request.

the more indirect sales. If industry v 's output in country k is completely sold to final consumers, U_k^v equals unity. If a part of the output is sold as intermediates, U_k^v is above one and a higher value of U_k^v associates with higher upstreamness. Accordingly, larger values of U_k^v are associated with increased distance to final consumption.

We use the WIOD to apply this methodology to the Indian economy. We exclude non-tradable industries in the construction of our key dependent variable.³⁶ Table 5.1 shows summary statistics of the derived industry upstreamness measure for 34 tradable 2-digit industries based on the ISIC-4 classification. In our period, the average upstreamness of Indian industries varies between 1.22 (water

Table 5.1: Industry upstreamness measure for India

ISIC-4 Industry	mean	sd	min	max
Mining and quarrying	3.80	0.18	3.52	4.08
Manufacture of chemicals and chemical products	3.33	0.06	3.21	3.40
Manufacture of coke and refined petroleum products	2.79	0.20	2.52	3.05
Manufacture of basic metals	2.71	0.07	2.60	2.80
Manufacture of paper and paper products	2.63	0.08	2.48	2.74
Manufacture of other non-metallic mineral products	2.34	0.03	2.29	2.42
Manufacture of rubber and plastic products	2.33	0.03	2.28	2.40
Manufacture of fabricated metal products, except machinery and equipment	2.27	0.04	2.20	2.32
Telecommunications	2.24	0.10	2.08	2.42
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	2.17	0.06	2.05	2.24
Manufacture of computer, electronic and optical products	2.14	0.20	1.93	2.58
Wholesale and retail trade and repair of motor vehicles and motorcycles	2.10	0.06	2.02	2.20
Warehousing and support activities for transportation	2.07	0.07	1.96	2.18
Retail trade, except of motor vehicles and motorcycles	2.07	0.05	1.99	2.15
Wholesale trade, except of motor vehicles and motorcycles	2.07	0.05	1.99	2.15
Manufacture of electrical equipment	2.00	0.10	1.88	2.17
Printing and reproduction of recorded media	2.00	0.07	1.88	2.12
Legal and accounting activities; activities of head offices; management consultancy activities	2.00	0.07	1.86	2.08
Land transport and transport via pipelines	1.95	0.05	1.87	2.03
Manufacture of machinery and equipment n.e.c.	1.94	0.07	1.83	2.05
Manufacture of furniture; other manufacturing	1.90	0.10	1.77	2.08
Forestry and logging	1.88	0.05	1.81	1.97
Manufacture of other transport equipment	1.84	0.21	1.58	2.19
Crop and animal production, hunting and related service activities	1.78	0.06	1.65	1.83
Architectural and engineering activities; technical testing and analysis	1.71	0.15	1.51	1.97
Other service activities	1.66	0.07	1.52	1.80
Manufacture of textiles, wearing apparel and leather products	1.63	0.05	1.55	1.71
Manufacture of motor vehicles, trailers and semi-trailers	1.61	0.09	1.49	1.75
Manufacture of food products, beverages and tobacco products	1.54	0.06	1.42	1.61
Manufacture of basic pharmaceutical products and pharmaceutical preparations	1.51	0.03	1.47	1.56
Air transport	1.51	0.14	1.26	1.71
Computer programming, consultancy and related activities; information service activities	1.46	0.09	1.29	1.59
Construction	1.34	0.04	1.28	1.44
Water transport	1.22	0.05	1.17	1.37
Across all industries	2.05	0.54	1.17	4.08

Source: Own calculation based Antràs and Chor (2018) and WIOD data.

Note: Only tradable industries are considered.

transport) and 3.80 (mining and quarrying). Across all industries, the average upstreamness is 2.05. The maximum value for upstreamness (4.08) is measured in the *mining and quarrying* industry in 2008 and the minimum (1.17) is measured in the *water transport* industry in 2012. Looking at manufacturing industries only, the most downstream manufacturing industry is *manufacture of basic pharmaceutical products and pharmaceutical preparations* (1.51), while *manufacture of chemicals and chemical products* (3.33) is the most upstream one.

Next, we combine the industry-level upstreamness measure with product-level sales information to obtain a measure of upstreamness at the firm-level. For each firm-year observation, we use the product-level sales shares as weights to calculate the weighted average of upstreamness of the firms' product portfolio as illustrated in equation (5.26), so that

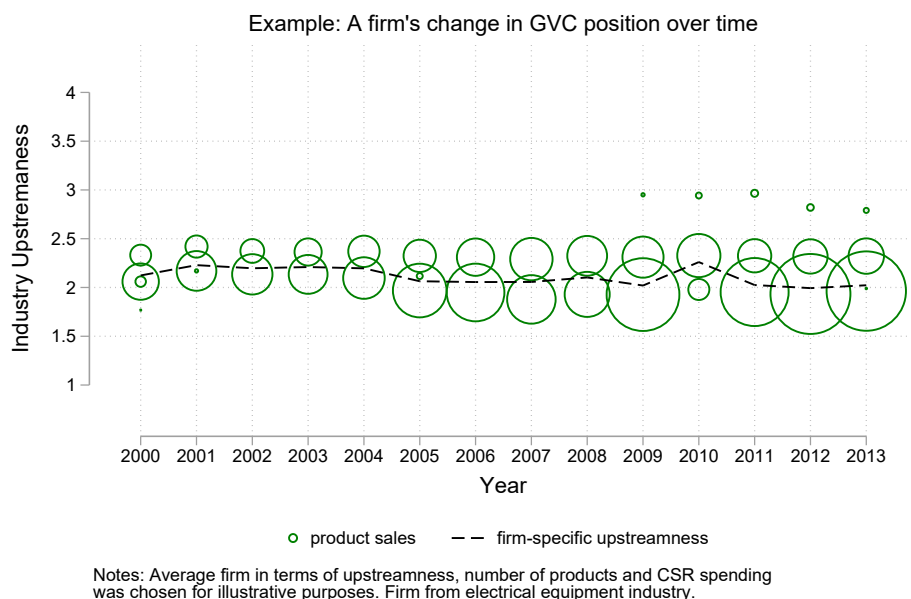
$$U_{ft} = \sum_{v=1}^V \frac{sales_{fvt}}{sales_{ft}} U_{vt}, \quad (5.26)$$

³⁶We base the classification of industries as non-tradable on the export pattern revealed in WIOD. To avoid that an industry with negligibly small exports is defined as tradable in one year and as non-tradable in the next year, we define a threshold, above which an industry is classified as tradable. The threshold is defined as the lowest amount that avoids any switching between being classified as tradable or non-tradable during our covered period. The exclusion of non-tradable industries affects 20 industries in WIOD, e.g., *public administration and defence; compulsory social security, education and accommodation and food service activities*.

where U_{ft} is the level of upstreamness of firm f at time t selling products from V different industries.³⁷ The measure accounts for the product mix by weighting a product's GVC position U^{vt} with its share of total sales in year t .³⁸

Our measure of a firm's GVC position U_{ft} has three sources of variation. First, the measure is affected by changes in a firm's product portfolio, i.e., if a firm drops or adds new products. Second, for a given product mix, the relative importance of the different products may change. Third, the GVC position of the different products in a firm's portfolio changes over time (e.g., because some of the firm's products are increasingly used in more downstream industries). Figure 5.1 illustrates these sources of variation for a firm in the electrical equipment industry. This firm serves as an example of an average firm in our sample in terms of CSR spending, upstreamness and number of products. It has several

Figure 5.1: A firm's GVC position change over time



products that belong to industries that differ in terms of the upstreamness position. Over time, the firm's product portfolio changes as a new product is added and one is dropped and the importance of products measured by their sales share changes as well. The firm's upstreamness position (black dashed line) varies over time in line with the changes in the product portfolio.

5.3.3 Empirical Specification

We start the discussion of the empirical methodology with a description of the main empirical setup, including the presentation of other independent variables, which may drive CSR decisions of firms. After discussing descriptive statistics, we present the empirical results.

³⁷Our approach is comparable to the approach by Chor et al. (2021), who also combine an industry GVC measure with a firm's product information. They use firms' exports (imports) in an industry in total exports (imports) as weights to derive a firm-specific GVC position for Chinese firms. Similar to our derived GVC measure, the respective GVC measure varies over time within a firm.

³⁸For some firms, there is no product-level information available. In these cases, we take the upstreamness of the main industry of the firm as the measure of the GVC position. This affects 8.49% of the observations, which enter our empirical estimation.

5.3.3.1 Empirical Set-Up

Proposition 1 predicts that CSR expenditures increase along the value chain from upstream to downstream stages. To empirically test this prediction, we estimate the following two equations.

$$Y_{fvt} = \alpha_0 + \beta_1 U_{ft-1} + \beta_2 X_{ft-1} + \gamma_{vt} + \delta_s + \epsilon_{fvt}, \quad (5.27)$$

$$Y_{fvt} = \alpha_0 + \beta_1 U_{ft-1} + \beta_2 X_{ft-1} + \zeta_f + \tau_t + \epsilon_{fvt}, \quad (5.28)$$

where Y_{fvt} measures CSR spending of firm f active in main industry v in year t . In our main specifications, we apply two different estimators, OLS and Poisson Pseudo-Maximum Likelihood (PPML). To apply OLS, we take the natural logarithm of a firm's CSR spending ($\log(\text{CSR spending}_{ft})$). This removes firms with zero CSR spending from our sample. Our alternative specification applying PPML with $\text{CSR spending}_{fvt}$ as the dependent variable allows us to keep zeros in the data.³⁹ Our main explanatory variable of interest is a firm's GVC position at time $t - 1$, U_{ft-1} . In all regressions, we expect $\beta_1 < 0$, which indicates lower CSR spending for more upstream firms.

In our choice of fixed effects, we use two different approaches to analyze the relation between CSR spending and upstreamness. First, equation (5.27) is a repeated cross-section in which we include state δ_s and industry-year γ_{vt} fixed effects. We include state fixed effects δ_s to capture differences between Indian states which may affect the level of CSR spending in all firms alike, for example, differences in labor regulation. The industry-year fixed effects γ_{vt} capture shocks common to all firms in a particular industry and year. Some industries may be under tighter public scrutiny in general (e.g., tobacco), or there might be industrial disasters that affect certain industries in specific years. Accordingly, equation (5.27) exploits variation *between* firms within the same state, main industry, and year.

Second, equation (5.28) exploits time-series variation within firms. We only include firm fixed effects ζ_f and year fixed effects τ_t . ζ_f captures unobservable firm characteristics, which are time-invariant. τ_t captures year-specific shocks to CSR spending common to all firms. In this specification, we thus exploit within-firm variation over time. In our data, we observe a firm 6.8 years on average.

X_{ft-1} includes firm-level control variables to capture alternative drivers of CSR spending. Similar to U_{ft-1} , the control variables enter with a one-year time lag. We next present these control variables in more detail.

The variable $\log(\text{Wages})$ is a proxy for firm-level wage payments to control for the possibility that wages vary systematically with the value chain position. One could consider staff welfare spending a part of the overall compensation package for employees. If downstream firms offer better compensation packages (e.g., due to higher skill intensity), a negative relationship between upstreamness and CSR spending (partly measured by staff welfare spending) could then be interpreted as actually reflecting the negative relationship between upstreamness and employee compensation. We control for this by taking the hourly compensation paid in Indian industries from WIOD and using the product-level information of firms to generate a firm-level control variable that is similar in spirit to our firm-level upstreamness measure.⁴⁰ In particular, we calculate *wages* as an industry's average hourly compensation to employees

³⁹PPML is widely used in the literature of international economics and does not require taking the natural logarithm of the dependent variable. Thus, using PPML also allows us to explore within firm variation over time for those firms that start spending on CSR during our analyzed period. Moreover, it outperforms its alternatives in the presence of many zeros and heteroskedasticity (Silva and Tenreyro, 2006).

⁴⁰The wage bill is available for a subset of firms in Prowess. However, since there are many zeros and because the provision of the number of employees is not compulsory for firms, we decide not to include the wage bill and prefer to use our combined measure.

weighted by a firm’s product sales in the respective industry and year.⁴¹ The variable *export share* captures a firm’s internationalization as the share of export sales in total sales. In introducing this control variable, we follow Newman et al. (2018) who find that exporting firms are more likely to invest in CSR. They argue that a key driver is a change of stakeholder preferences with entry into export markets. Internationalization broadens the set of stakeholders, also including foreign governments, buyers of intermediates and consumers. The variable *OECD export exposure* controls for the possibility that some firms are more exposed to more demanding markets. The variable builds on the assumption that stakeholders in OECD countries are, on average, more demanding. This measure is constructed similar to our upstreamness and wage measures based on WIOD industry data as an industry’s exports to OECD countries relative to the industry’s total exports weighted with a firm’s product portfolio.⁴² The variable *domestic inputs/all inputs* proxies for a firm’s local embeddedness. It is calculated as the share of domestically sourced inputs over all inputs. Newman et al. (2020) argue that dependence on local inputs positively affects firms’ social activities within their community. The dummies *state owned* and *foreign owned* capture differences in shareholder preferences depending on the type of ownership. For example, Brucal et al. (2019) show that Indonesian firms improve their CO2-efficiency after foreign acquisition. Finally, the variable *log(Sales)* controls for size and *log(Age)* for the age of a firm. Both variables are calculated by taking the respective natural logarithm. In both specifications, we cluster the error terms ϵ_{fvt} at the firm-level. We now turn to the presentation of descriptive statistics.

5.3.3.2 Descriptive Statistics

Table 5.2 reports summary statistics of all relevant variables based on the sample employed in the empirical estimations. On average, firms spend 141,268 USD per year on CSR. The highest amount spent on CSR in the sample, USD 142 million in 2006, is spent by a firm active in the *machinery and equipment* industry, producing 51 products spanning ten WIOD industries.

In the overall sample, the average level of firm-specific upstreamness is 2.05, with values ranging from 1.17 to 4.08. The firms reporting product-level information produce on average 2.95 products from 1.52 WIOD industries. The multi-product nature of most firms illustrates that it is not sufficient to control only for the main product’s GVC position because this would neglect differences in GVC positions across the firm’s products. In terms of internationalization, 6.49% of the firms are foreign-owned and the firms export on average 11.36% of sales.

Table 5.2: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CSR (USD)	81,749	141,268.6	1,260,149	0	142,000,000
log CSR (USD)	54,397	10.16	1.83	7.13	18.77
Upstreamness	81,749	2.05	0.54	1.17	4.08
Wages (in Rupee)	81,749	27.23	12.70	6.82	119.78
log Wages (in Rupee)	81,749	3.21	0.43	1.92	4.79
OECD export exposure	81,749	0.31	0.22	0.00	0.86
Export share	81,500	0.11	0.25	0.00	1.00
Domestic inputs/total inputs	81,749	0.35	0.44	0.00	1.00
State owned	81,749	0.00	0.04	0.00	1.00
Foreign owned	81,014	0.06	0.25	0.00	1.00
Sales (million USD)	79,638	46.11	409.81	0.001	64213.24
log Sales (million USD)	79,638	1.48	2.51	-6.68	11.07
Age (years)	81,749	20.98	16.64	0	150
log Age (years)	81,736	2.78	0.74	0.00	5.01
number of products	74,809	2.95	2.31	1.00	51.00
number of 2-digit industries per firm	74,809	1.52	0.80	1.00	10.00

Source: CMIE Prowess.

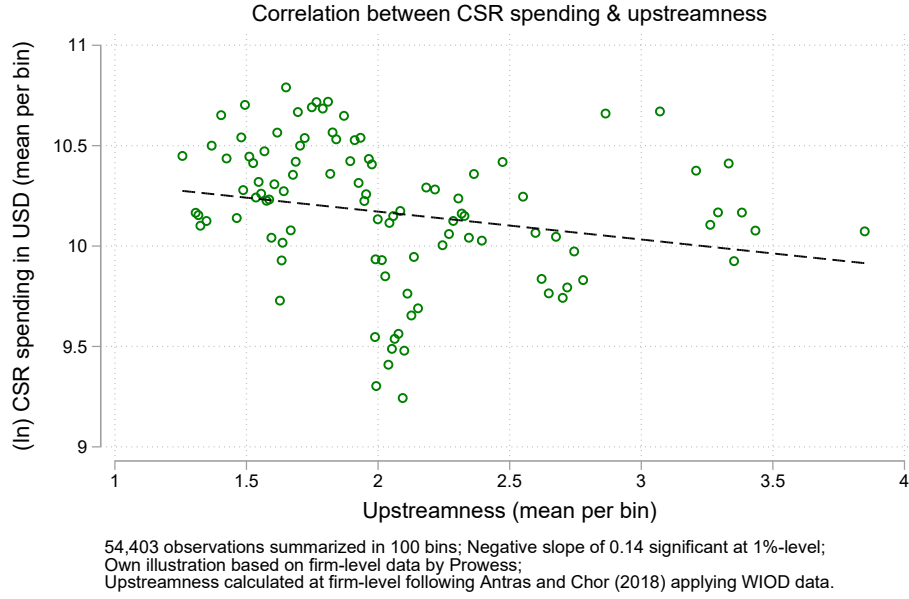
Note: Only tradable industries are considered.

Figure 5.2 illustrates in a binscatter plot the correlation between firms’ CSR spending and their GVC position. Each dot represents the mean CSR spending per upstreamness bin. This figure shows that

⁴¹See Appendix 5.6 for more details on the calculation.

⁴²See Appendix 5.6 for more details on the calculation.

Figure 5.2: Correlation between firms' CSR and GVC position



there is on average lower CSR spending among firms with a more upstream GVC position. We test this pattern more rigorously using equations (5.27) and (5.28) described above.

5.3.3.3 Empirical Results

Table 5.3 shows our key empirical results. Columns (1) to (3) present results for the cross-sectional specifications based on equation (5.27) and columns (4) to (6) present those for the panel specification based on equation (5.28). The cross-section OLS estimation is shown in column (1). Since we take the natural logarithm of CSR spending, firms without any CSR spending in a respective year do not enter the sample. Columns (2) and (3) report results from PPML estimations. Column (2) serves as a bridge between OLS and the full PPML as it reports the PPML results for the sample of firms reporting positive CSR spending only. Column (3) shows the results of the PPML estimation including firms with zero CSR spending, which allows us to use a substantially larger sample.

In the cross-sectional estimations, the unrestricted sample includes 81,749 observations (column (3)), while the exclusion of firms reporting zero CSR spending reduces the sample to 54,394 observations (columns (1) and (2)).

Upstreamness is negative and significant in all three specifications. The coefficients are quite stable across specifications, ranging between -0.21 and -0.23. Firms that are located more upstream have lower CSR spending compared to firms that are more downstream. We take this finding on the relationship between CSR spending and a firm's GVC position as support for our model's prediction of higher CSR spending in more downstream firms.

In the panel estimations in columns (4) to (6), we report the results from the specification that exploits time variation within firms. Except for the fixed effects structure, they mirror columns (1) to (3). Again, we find the expected negative effect for upstreamness. It is significant at the 1%-level in all three specifications. The OLS estimation and the PPML estimation excluding zero CSR spending exploit information from 8,533 firms and 51,645 observations in total, respectively. The specification of column (6) also includes firms which report zero CSR spending in some years. This increases the number of observations to 64,851 and the number of firms to 9,596. Again, we take the significant findings of the panel estimations as empirical support for our theoretical prediction of increasing CSR spending along

Table 5.3: Regression results

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	(ln) CSR OLS	cross section CSR in USD PPML w/o zeros	CSR in USD PPML incl. zeros	(ln) CSR OLS	panel CSR in USD PPML w/o zeros	CSR in USD PPML incl. zeros
Upstreamness	-0.211*** (0.051)	-0.234** (0.104)	-0.225** (0.108)	-0.135*** (0.039)	-0.184*** (0.061)	-0.170*** (0.060)
OECD export exposure	0.086 (0.105)	0.567** (0.235)	0.651*** (0.231)	0.288*** (0.065)	0.533*** (0.118)	0.567*** (0.120)
log(Wages)	0.238*** (0.078)	-0.083 (0.190)	-0.053 (0.192)	0.223*** (0.039)	0.009 (0.096)	0.010 (0.097)
Export share	0.379*** (0.046)	0.149 (0.187)	0.200 (0.186)	0.143*** (0.040)	0.222*** (0.083)	0.265*** (0.083)
Domestic inputs/total inputs	0.228*** (0.027)	0.245*** (0.078)	0.323*** (0.078)	0.041** (0.018)	0.045 (0.033)	0.081** (0.034)
State-owned (D)	0.520* (0.273)	0.139 (0.172)	0.161 (0.181)	0.148 (0.169)	0.049 (0.094)	0.050 (0.094)
Foreign-owned (D)	1.037*** (0.046)	0.522*** (0.093)	0.562*** (0.095)	0.048 (0.049)	0.188*** (0.065)	0.193*** (0.067)
log(Sales)	0.582*** (0.008)	0.857*** (0.028)	0.881*** (0.028)	0.315*** (0.010)	0.463*** (0.025)	0.472*** (0.025)
log(Age)	0.219*** (0.015)	0.197*** (0.051)	0.221*** (0.051)	0.141*** (0.030)	0.302*** (0.063)	0.323*** (0.063)
Industry x Year & State (D)	Yes	Yes	Yes	No	No	No
Firm (D)	No	No	No	Yes	Yes	Yes
Year (D)	No	No	No	Yes	Yes	Yes
Observations	54,394	54,394	81,749	51,645	51,645	64,851
Number of firms	11,291	11,291	15,512	8,533	8,533	9,596
Pseudo/Adjusted R ²	0.577	0.837	0.842	0.140 ^a	0.975	0.969

Robust standard errors in parentheses clustered at the firm-level; ^aadjusted within R²

*** p<0.01, ** p<0.05, * p<0.1

the GVC. Firms that become more upstream over time spend less on CSR on average.

To analyze the economic relevance of the findings, Figure 5.3 illustrates the predicted level of CSR spending based on the first four columns, while varying the GVC position and holding all other variables constant at their means.⁴³

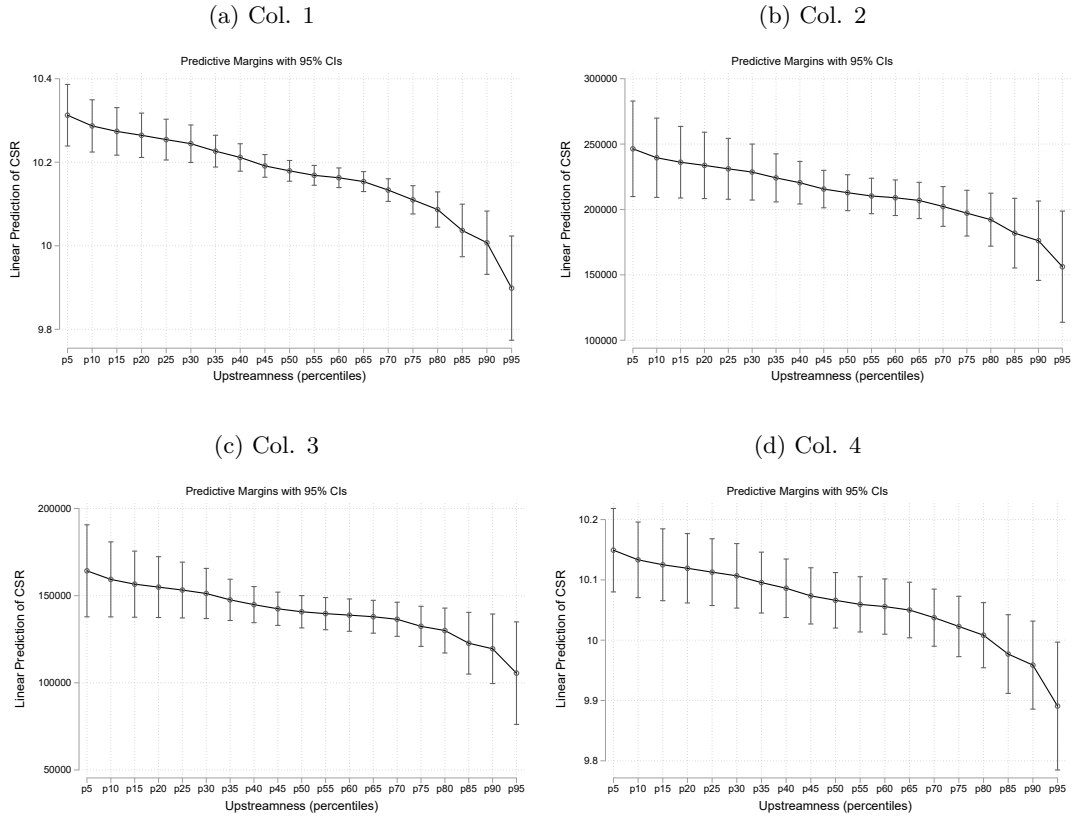
In all four columns, the negative relationship is visible across all percentiles. Turning to the graph based on column (3), which includes also zero reported CSR spending, we find at the fifth percentile a predicted CSR spending of 164,130 USD compared to 105,679 USD at the 95th percentile. Accordingly, comparing a very upstream position with U_{ft-1} equal to 3.29 to a very downstream position with U_{ft-1} equal to 1.33 increases the predicted CSR spending by 55.31%, which is arguably an economically relevant magnitude.

Our empirical estimations thus strongly support our main prediction that more downstream firms spend more on CSR. The empirical finding is both statistically significant and economically meaningful.

Besides the effect of the value chain position on CSR spending, which is a novelty in the literature on CSR determinants, also the findings concerning our control variables provide some interesting insights for this literature. We find only tentative support in columns (1) and (4) that a firm's CSR spending increases with the wage level. On the one hand, this suggests that focusing purely on wages paid by firms does not sufficiently capture its goodwill towards employees and society. However, when interpreting our results one has to bear in mind that we neither have wage bill information of the firms nor a split of wages by skill-levels. Moreover, we find strong indication of a positive relationship between exposure to a highly demanding market and CSR spending. Firms producing in sectors with a high share of exports towards OECD countries do engage significantly more in CSR in five out of six specifications. An increase in exports relative to total sales significantly increases a firm's CSR spending. The latter effect is significant in all panel estimations and the OLS estimation of the cross-section. Accordingly, we can conclude that an increase in export activity is associated with the level of CSR spending. This result speaks to the role of export markets in incentivizing suppliers' social activities and is in line with Newman et al. (2018). Moreover, domestic linkages are a powerful determinant of CSR spending and

⁴³The marginal effects of linear models with fixed effects (like our columns 1-4) can be computed and illustrated as in Figure 3. This is not possible in a non-linear model with fixed effects (our columns 5 and 6).

Figure 5.3: A firm's GVC positioning and predicted CSR spending



are significant at the 1%-percent level in all cross sectional specifications and at the 5% level in two panel specifications. We take this as empirical support for the claim that firms with strong regional ties also commit to regional sustainable development, including spending on social and community CSR (Newman et al., 2020). Finally, we turn to the role of shareholders. While state ownership is significant only in one specification, foreign ownership is significant in five out of six specifications. The latter might reflect the commitment of foreign owners to international standards in labor conditions, including CSR activities.

5.3.4 Robustness

To analyze the robustness of our results, we run further alternative specifications. First, we smooth CSR spending over two years to control for the possibility that firms' CSR spending concentrates around a specific year. Second, we control for firms' advertising expenses to control for the fact that higher CSR expenditure by firms in more downstream industries could be driven by their greater visibility to final consumers.

5.3.4.1 Smoothed CSR Spending

Like other forms of firm spending (e.g., investments), CSR might vary from year to year. For instance, a firm might make substantial investments in the community infrastructure in one year and refrain from further CSR spending in the following years. To account for this, we smooth CSR spending by taking the moving average of two years, more precisely, years t and $t - 1$, as the dependent variable. We present the results of this robustness check in Table 5.4.

Table 5.4: Robustness check: Smoothed CSR spending

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	(ln) CSR OLS	cross section CSR in USD PPML w/o zeros	CSR in USD PPML incl. zeros	(ln) CSR OLS	panel CSR in USD PPML w/o zeros	CSR in USD PPML incl. zeros
Upstreamness	-0.211*** (0.048)	-0.277*** (0.103)	-0.274** (0.107)	-0.148*** (0.035)	-0.247*** (0.053)	-0.229*** (0.053)
OECD export exposure	0.189* (0.097)	0.617*** (0.229)	0.698*** (0.225)	0.286*** (0.057)	0.529*** (0.125)	0.573*** (0.123)
log(Wages)	0.248*** (0.071)	-0.029 (0.181)	0.004 (0.183)	0.251*** (0.036)	0.054 (0.089)	0.055 (0.089)
Export share	0.391*** (0.045)	0.117 (0.203)	0.155 (0.202)	0.162*** (0.036)	0.191** (0.077)	0.208*** (0.076)
Domestic inputs/total inputs	0.236*** (0.026)	0.262*** (0.078)	0.322*** (0.079)	0.045*** (0.016)	0.076** (0.030)	0.093*** (0.030)
State-owned (D)	0.553* (0.284)	0.168 (0.160)	0.185 (0.165)	0.127 (0.148)	-0.099** (0.042)	-0.096** (0.040)
Foreign-owned (D)	1.097*** (0.046)	0.561*** (0.090)	0.592*** (0.092)	0.056 (0.054)	0.101 (0.072)	0.106 (0.072)
log(Sales)	0.543*** (0.007)	0.852*** (0.025)	0.870*** (0.026)	0.275*** (0.008)	0.501*** (0.022)	0.509*** (0.022)
log(Age)	0.265*** (0.014)	0.257*** (0.052)	0.275*** (0.053)	0.223*** (0.028)	0.435*** (0.062)	0.459*** (0.063)
Industry x Year & State (D)	Yes	Yes	Yes	No	No	No
Firm dummy	No	No	No	Yes	Yes	Yes
Year (D)	No	No	No	Yes	Yes	Yes
Observations	59,090	59,090	81,749	56,706	56,706	65,839
Number of firms	11,660	11,660	15,512	9,269	9,269	9,823
Pseudo/Adjusted R ²	0.592	0.847	0.851	0.192 ^a	0.983	0.980

Robust standard errors in parentheses clustered at the firm-level; ^aadjusted within R²
*** p<0.01, ** p<0.05, * p<0.1

The results continue to support our theoretical prediction. The effect of upstreamness on CSR remains negative and statistically significant when using smoothed CSR spending. It is significant at the 5%-level in column (3) and at the 1%-level in the remaining five specifications.

5.3.4.2 Controlling for Visibility

More downstream firms are closer to final consumers and may therefore be more visible. Higher visibility may for example increase the probability that some infringement is recognized and/or sanctioned by consumers. In this case, higher visibility would provide an additional incentive for CSR investments and our findings could be driven by the visibility of firms rather than their GVC position. Customer awareness can be proxied by spending on marketing and advertising (Servaes and Tamayo, 2013). Firms with higher marketing expenses are more visible. The same could be true for more downstream firms as it may be easier for customers to observe firms that are closer to the final product. Table 5.5 shows the results when we control for our proxy of visibility, a firm's *selling and distribution expenses*, which include marketing, advertising and distribution spending.

The sample size of our broadest sample (column (3)) is reduced by 21% compared to our main results in Table 5.3, as not all firms report on marketing expenses. However, we still cover a large part of the sample. CSR and marketing expenses are indeed highly correlated, but the effect of upstreamness on firms' CSR spending does remain statistically significant and economically meaningful. This shows that while the visibility seems to have merit for a firm's CSR decision, there is a separate and distinct role of upstreamness in determining CSR expenditure, giving further support to our model's prediction of the role of incomplete contracts in the determination of CSR spending along the value chain.

5.4 Conclusion

Globalized value chains involving developing and emerging economies characterize modern-day production. With different stages of production being performed in different countries, they are also performed in very diverse regulatory environments. With consumers in the Global North more and more concerned about the environmental and social footprints of their consumption choices, firms are increas-

Table 5.5: Regression results: Controlling for selling expenses

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	(ln) CSR OLS	cross section CSR in USD PPML w/o zeros	CSR in USD PPML incl. zeros	(ln) CSR OLS	panel CSR in USD PPML w/o zeros	CSR in USD PPML incl. zeros
Upstreamness	-0.222*** (0.050)	-0.251** (0.105)	-0.247** (0.108)	-0.089** (0.040)	-0.163** (0.065)	-0.149** (0.065)
OECD export exposure	0.121 (0.103)	0.386* (0.207)	0.439** (0.205)	0.330*** (0.068)	0.552*** (0.127)	0.600*** (0.128)
log(Wages)	0.266*** (0.082)	-0.147 (0.195)	-0.113 (0.196)	0.173*** (0.040)	0.013 (0.100)	0.003 (0.100)
Export share	0.189*** (0.048)	0.261*** (0.092)	0.269*** (0.093)	0.101** (0.042)	0.165* (0.085)	0.163* (0.085)
Domestic inputs/total inputs	0.187*** (0.026)	0.177** (0.073)	0.214*** (0.073)	0.051*** (0.019)	0.045 (0.032)	0.073** (0.033)
State-owned (D)	0.445* (0.236)	0.125 (0.152)	0.147 (0.157)	0.166 (0.173)	0.053 (0.093)	0.053 (0.093)
Foreign-owned (D)	0.881*** (0.044)	0.457*** (0.083)	0.487*** (0.085)	0.037 (0.047)	0.185** (0.073)	0.189** (0.075)
log(Sales)	0.431*** (0.011)	0.743*** (0.041)	0.757*** (0.041)	0.310*** (0.012)	0.464*** (0.034)	0.472*** (0.034)
log(Age)	0.213*** (0.015)	0.210*** (0.046)	0.222*** (0.047)	0.133*** (0.031)	0.330*** (0.067)	0.342*** (0.066)
log(Adv Market Exp)	0.226*** (0.008)	0.110*** (0.023)	0.117*** (0.023)	0.083*** (0.006)	0.029 (0.018)	0.029 (0.018)
Industry x Year & State (D)	Yes	Yes	Yes	No	No	No
Firm (D)	No	No	No	Yes	Yes	Yes
Year (D)	No	No	No	Yes	Yes	Yes
Observations	49,400	49,400	64,379	47,064	47,064	55,498
Number of firms	10,180	10,180	12,720	7,832	7,832	8,460
Pseudo/Adjusted R ²	0.616	0.844	0.845	0.162 ^a	0.975	0.971

Robust standard errors in parentheses clustered at the firm-level; ^aadjusted within R²

*** p<0.01, ** p<0.05, * p<0.1

ingly under pressure to assure that certain minimum standards are not only respected by the firm itself, but also by suppliers along its GVC.

In our model, CSR along the value chain provides ethical product differentiation and allows the firm to set a price above marginal cost to caring consumers. We extend the common notion of contractual incompleteness in supply chain relationships to the provision of CSR along the value chain. Building on the model of sequential production by Antràs and Chor (2013), we analyze CSR investments by a continuum of independent suppliers along the value chain. We find an increasing CSR profile with more downstream suppliers featuring higher CSR expenditures.

We confirm this prediction using Indian firm-level data. Merging product-level information with the World Input-Output Database (WIOD), we construct a measure of a firm's GVC position. Using combined staff welfare spending and social community spending as our measure of CSR expenditure, we find strong support for our prediction. Our results are robust to the inclusion of a large set of fixed effects, control variables and several robustness checks. Most notably, our results hold when we control for firm level wages and the firm's visibility.

Our main results are highly relevant for policy makers. Most importantly, our analysis reveals that the economic incentives for CSR investments are lowest in upstream industries. Concerning laws on corporate sustainability due diligence, this implies that the obligation of firms to assure ethical standards along their supply chain is particularly difficult to meet for upstream suppliers. By the same token, when the aim of the policy maker is to attain high levels of CSR along the entire value chain, our results show that efforts should be focused on suppliers in more upstream industries. Finally, for governments aiming at decent work and economic growth (as specified in the UN's Sustainable Development Goal 8) the fact that more upstream stages of production are characterized by low CSR investments, provides an incentive to strategically focus industrial policy towards specialization in more downstream production stages.

In this paper, we highlight the relevance of incomplete contracts for CSR investments depending on the value chain position of the supplier. Introducing contractual incompleteness for CSR and ethical production in global value chains opens up a whole range of promising avenues for future research. Especially so, as it opens up the rich theoretical and empirical toolkit of the literature on the international

organization of production to the analysis of CSR and ethical production in global value chains involving developing and emerging economies. In this context, future research should further investigate the relevance of incomplete contracts for CSR in global production. To this end, new theories could be developed to neatly link existing or novel empirical measures of contractual incompleteness to firm's CSR investments.

5.5 Theory Appendix

5.5.1 Industry Equilibrium with Incomplete Contracts

We use equation (5.19) to calculate the values of $q(\omega)$ and $s(m)$ in industry equilibrium from equations (5.17) and (5.14).

$$q(\omega) = \frac{\rho}{c_x} \frac{f}{1-2\rho} \quad (5.29)$$

$$s(m) = \frac{1-\alpha}{\beta} \frac{(1-\beta)\rho}{c_s} \frac{f}{1-2\rho} m^{\frac{\rho-\alpha}{\alpha(1-\rho)}} \quad (5.30)$$

Using the definition of $\varepsilon(\omega)$ we then get

$$\varepsilon(\omega) = \left(\int_0^1 s(m)^\alpha dm \right)^{\frac{1}{\alpha}} = \frac{1-\alpha}{\beta} \frac{(1-\beta)\rho}{c_s} \frac{f}{1-2\rho} \left(\frac{1-\rho}{1-\alpha} \right)^{\frac{1}{\alpha}}. \quad (5.31)$$

Plugging this, the solution for $q(\omega)$, as well as the expression for P into inverse demand gives the pricing rule as

$$p(\omega) = A^{1-\rho} q(\omega)^{-(1-\rho)} \varepsilon(\omega)^\rho = \frac{c_x}{\rho} \frac{1-\rho}{\beta}. \quad (5.32)$$

Using $\varepsilon(\omega)$ and $p(\omega)$ in the definition of the price index from demand, $P^{-\frac{\rho}{1-\rho}} = \int_0^n \left(\frac{\varepsilon(\omega)}{p(\omega)} \right)^{\frac{\rho}{1-\rho}} d\omega$, gives equation (5.20), a second expression for the price index as a function of the number of firms, n . Combining the two expressions gives the equilibrium number of firms from equation (5.21),

$$n = \frac{\beta E}{1-\rho} \frac{1-2\rho}{f}. \quad (5.33)$$

5.5.2 Complete Contracts

In this section, we solve the model for the case of complete contracts. Under complete contracts, the headquarter can offer fully specified contracts to each supplier j and will approach them in the right order. The headquarter offers a contract consisting of a physical quantity $x(j)$ and an according payment $w(j)$, as well as an implemented production standard $s(j)$ with the according payment $t(j)$. To make comparison with the baseline model feasible, we denote all endogenous variables in the complete contracts case with a tilde. The headquarter then maximizes its profits with respect to the four choice variables above, subject to two conditions:

$$\begin{aligned} \max_{\{\tilde{x}(j), w(j), \tilde{s}(j), t(j)\}_{j \in [0,1]}} \quad & \tilde{\pi}_F(\omega) = \tilde{q}(\omega)^\rho \tilde{A}^{1-\rho} \left(\int_0^1 \tilde{s}(j)^\alpha dj \right)^{\frac{\rho}{\alpha}} - \int_0^1 w(j) dj - \int_0^1 t(j) dj - f \\ \text{s.t.} \quad & w(j) - c_x \tilde{x}(j) \geq 0 \\ & t(j) - c_s \tilde{s}(j) \geq 0 \end{aligned}$$

Due to the large number of available suppliers, the headquarter can lower the payments $w(j)$ and $t(j)$ so that the constraints are binding and the supplier walks away with zero profits. Because $\tilde{x}(j) = \tilde{q}(\omega)$, we have

$$\int_0^1 w(j) dj = c_x \int_0^1 \tilde{x}(j) dj = c_x \tilde{q}(\omega). \quad (5.34)$$

and because of the binding constraints, $\int_0^1 t(j) dj = c_s \int_0^1 \tilde{s}(j) dj$.

This implies that we can restate the headquarter's problem in terms of $\tilde{q}(\omega)$ and $\tilde{s}(j)$ as

$$\tilde{q}(\omega), \{\tilde{s}(j)\}_{j \in [0,1]} \max \tilde{\pi}_F(\omega) = \tilde{q}(\omega)^\rho \tilde{A}^{1-\rho} \left(\int_0^1 \tilde{s}(j)^\alpha dj \right)^{\frac{\rho}{\alpha}} - c_x \tilde{q}(\omega) - c_s \int_0^1 \tilde{s}(j) dj - f \quad (5.35)$$

Differentiating with respect to the choice variables gives the first order conditions

$$\begin{aligned} \tilde{q}(\omega) &= \frac{\rho \tilde{r}(\omega)}{c_x} \\ \tilde{s}(j)^{1-\alpha} &= \frac{\tilde{r}(\omega) \rho}{c_s} \left(\int_0^1 \tilde{s}(j)^\alpha dj \right)^{-1} \end{aligned}$$

Expressing $\left(\int_0^1 \dots dj \right)$ in terms of revenue $\tilde{r}(\omega)$ gives $\tilde{s}(j)$ conditional on a level of output $\tilde{q}(\omega)$ as

$$\tilde{s}(j) = \tilde{s} = \tilde{r}(\omega)^{\frac{\rho-\alpha}{\rho(1-\alpha)}} \tilde{A}^{\frac{\alpha(1-\rho)}{\rho(1-\alpha)}} \tilde{q}(\omega)^{\frac{\alpha}{1-\alpha}} \left(\frac{\rho}{c_s} \right)^{\frac{1}{1-\alpha}} \quad \forall j$$

The difference to equation (5.11) is that here stage j standard depends on total revenue $\tilde{r}(\omega)$ instead of revenue *up to* that stage $r(j)$.

Plugging this back into the revenue expression from the maximization problem gives equilibrium revenue $\tilde{r}(\omega)$ as a function of $\tilde{q}(\omega)$ as

$$\tilde{r}(\omega) = \tilde{A} \left[\tilde{q}(\omega) \frac{\rho}{c_s} \right]^{\frac{\rho}{1-\rho}} \quad (5.36)$$

Plugging the result for $\tilde{r}(\omega)$ back into \tilde{s} from above gives

$$\tilde{s} = \tilde{A} \tilde{q}(\omega)^{\frac{\rho}{1-\rho}} \left(\frac{\rho}{c_s} \right)^{\frac{1}{1-\rho}} \quad \forall j \quad (5.37)$$

This gives a symmetric equilibrium investment in the standard \tilde{s} at each stage j as a function of exogenous parameters and conditional on the scale of production $\tilde{q}(\omega)$.

We know from the first FOC that

$$\tilde{q}(\omega) = \frac{\rho \tilde{r}(\omega)}{c_x}$$

and using the result for $\tilde{r}(\omega)$ from equation (5.36) gives that the optimal scale of production is given by

$$\tilde{q}(\omega) = \left[\rho \left(\frac{\tilde{A}}{c_x} \right)^{1-\rho} c_s^{-\rho} \right]^{\frac{1}{1-2\rho}} \quad (5.38)$$

Combining the results of equations (5.37) and (5.38) gives equilibrium CSR investment at each stage

j as

$$\tilde{s} = \left[\rho \left(\frac{\tilde{A}}{c_s} \right)^{1-\rho} c_x^{-\rho} \right]^{\frac{1}{1-2\rho}} \quad \forall j \quad (5.39)$$

Using the fact that with free entry, profits are zero for all (homogeneous) firms, and applying this to equation (5.35) gives the first expression for the equilibrium price index as

$$\tilde{P} = \rho^{-2} c_s c_x \left(\frac{f}{1-2\rho} \right)^{\frac{1-2\rho}{\rho}} E^{-\frac{1-\rho}{\rho}} \quad (5.40)$$

Plugging this into equation (5.39) for $\tilde{A} = E\tilde{P}^{\frac{\rho}{1-\rho}}$ gives

$$\tilde{s} = \frac{\rho}{c_s} \frac{f}{1-2\rho}. \quad (5.41)$$

5.5.2.1 Level of CSR with Complete Contracts and Comparison to Incomplete Contracts

Under complete contracts, the optimal CSR investment is uniform across all production stages j and is given by $\tilde{s} = \frac{\rho}{c_s} \frac{f}{1-2\rho}$. The uniformity result arises because all stages in the production process enter symmetrically into the production of ethical quality. Therefore, a headquarter able to write complete contracts has no incentive to assign different levels of investments to suppliers at different stages along the value chain.

It is instructive to compare this result with our main result from equation (5.24). In fact, it is possible to express $s(m)$ as a function of the complete contracts result \tilde{s} as

$$s(m) = (1-\alpha) \frac{1-\beta}{\beta} m^{\frac{\rho-\alpha}{\alpha(1-\rho)}} \tilde{s}. \quad (5.42)$$

Under incomplete contracts, CSR levels are smaller than the CSR investments under complete contracts for all - even the most downstream - stages of production. To see this, consider the following: Under our assumption that $\alpha < \rho$ and because $s(m)$ is increasing in m , showing that $s(1) < \tilde{s}$ will be sufficient. This holds when $\beta > \frac{1-\alpha}{2-\alpha}$. Because $1/2 > \frac{1-\alpha}{2-\alpha}$, this condition is always satisfied under our maintained assumption of $\beta \geq 1/2$.⁴⁴ It is apparent that there are *two* reasons for underinvestment in the incomplete contracts case relative to complete contracts. First, there is a term that applies equally to all stages, which results from individual profit maximization of suppliers along the value chain. Second, m denotes the position in the value chain. So while there is underinvestment at each stage, the underinvestment is more severe for smaller m , i.e., further upstream.

5.5.2.2 Remaining Industry Equilibrium Results

For completeness, we also report the remaining variables of the industry equilibrium with complete contracts. Using $\tilde{A} = E\tilde{P}^{\frac{\rho}{1-\rho}}$ and equation (5.40) in equation (5.38), gives the production quantity in industry equilibrium as

$$\tilde{q}(\omega) = \frac{\rho}{c_x} \frac{f}{1-2\rho}.$$

⁴⁴Recall that $\beta \geq 1/2$ directly stems from Antràs (2003) and $0 < \alpha < \rho$ is discussed in Section 5.2.2.1.

Using this result in inverse demand

$$\tilde{p}(\omega) = \tilde{A}^{1-\rho} \tilde{\varepsilon}(\omega)^\rho \tilde{q}(\omega)^{\rho-1}$$

as well as the definition of $\tilde{\varepsilon}$

$$\tilde{\varepsilon}(\omega) = \left(\int_0^1 \tilde{s}(j)^\alpha dj \right)^{\frac{1}{\alpha}} = \tilde{s}$$

gives the optimal pricing rule as

$$\tilde{p}(\omega) = \frac{c_x}{\rho}. \quad (5.43)$$

With the definition of the optimal price index

$$\tilde{P} = \left(\int_0^{\tilde{n}} \left[\frac{\tilde{p}(\omega)}{\tilde{\varepsilon}(\omega)} \right]^{-\frac{\rho}{1-\rho}} d\omega \right)^{-\frac{1-\rho}{\rho}}$$

we get a second expression for the price index,

$$\tilde{P} = \frac{c_s c_x}{\rho^2} \frac{1-2\rho}{f} \tilde{n}^{-\frac{1-\rho}{\rho}}, \quad (5.44)$$

which, combined with (5.40) gives the equilibrium number of firms as

$$\tilde{n} = (1-2\rho) \frac{E}{f} \quad (5.45)$$

5.5.3 The Extended Model

In this section, we show that our main result continues to hold in an extended version of the model, in which we introduce an additional parameter $\nu \in (0, 1)$ that captures the scope of ethical quality differentiation. The extension generalizes the model outlined in Section 5.2 and collapses to the baseline version for $\nu = 1$. This extension allows us to relax the assumption of $\rho < 1/2$. In particular, for arbitrarily small ν , the maximum possible value ρ approaches one. See Footnote 15 for a discussion.

For expositional simplicity, we maintain the same notation as in the main text. It is well understood that the expressions in this section and in the main text are identical for $\nu = 1$ only.

In the model setup, the only change is in the utility function, which now reads as

$$U = \left(\int_{\omega \in \Omega} [\varepsilon(\omega)^\nu q(\omega)]^\rho d\omega \right)^{\frac{1}{\rho}}. \quad (5.46)$$

Utility maximization subject to the budget constraint gives inverse demand for variety ω as

$$p(\omega) = \varepsilon(\omega)^{\nu\rho} q(\omega)^{-(1-\rho)} A^{1-\rho}, \quad (5.47)$$

where $A = EP^{\frac{\rho}{1-\rho}}$ and $P^{-\frac{\rho}{1-\rho}} = \int_{\omega \in \Omega} \left(\frac{\varepsilon(\omega)^\nu}{p(\omega)} \right)^{\frac{\rho}{1-\rho}} d\omega$. Using the definition of $\varepsilon(\omega)$ given in equation (5.3), firm revenue can be written as

$$r(\omega) = \left(\int_0^1 s(j)^\alpha dj \right)^{\frac{\nu\rho}{\alpha}} q(\omega)^\rho A^{1-\rho} \quad (5.48)$$

5.5.3.1 Incomplete Contracts

With incomplete contracts, inverse demand and firm revenues are still given by equations (5.47) and (5.48).

Revenue secured up to stage m is given by

$$r(m) = q(\omega)^\rho A^{1-\rho} \left(\int_0^m s(j)^\alpha dj \right)^{\frac{\nu\rho}{\alpha}} \quad (5.49)$$

and the incremental contribution of stage m to overall revenue then follows as

$$\frac{\partial r(m)}{\partial m} = r'(m) = \frac{\nu\rho}{\alpha} s(m)^\alpha r(m)^{\frac{\nu\rho-\alpha}{\nu\rho}} q(\omega)^{\frac{\alpha}{\nu}} A^{\frac{(1-\rho)\alpha}{\nu\rho}}. \quad (5.50)$$

As in the baseline model, each supplier maximizes its profits, composed of the share $1 - \beta$ of the incremental contribution to final revenue net of expenditure for the production standard,

$$\max_{s(m)} \pi_s(m) = (1 - \beta) r'(m) - c_s s(m). \quad (5.51)$$

Differentiating these profits with respect to $s(m)$ gives the analog of equation (5.11) from the baseline model as

$$s(m) = \left[(1 - \beta) \frac{\nu\rho}{c_s} q(\omega)^{\frac{\alpha}{\nu}} A^{\frac{(1-\rho)\alpha}{\nu\rho}} \right]^{\frac{1}{1-\alpha}} r(m)^{\frac{\nu\rho-\alpha}{\nu\rho(1-\alpha)}}. \quad (5.52)$$

Plugging this back into equation (5.50) yields a differential equation analogous to equation (5.12) in the baseline model. The solution gives an expression for revenue secured up to stage m as a function of parameters, A , and $q(\omega)$ analogous to equation (5.13) as

$$r(m) = \left(\frac{1 - \nu\rho}{1 - \alpha} \right)^{\frac{\nu\rho(1-\alpha)}{\alpha(1-\nu\rho)}} \left(\frac{1 - \beta}{c_s} \nu\rho \right)^{\frac{\nu\rho}{1-\nu\rho}} A^{\frac{1-\rho}{1-\nu\rho}} q(\omega)^{\frac{\rho}{1-\nu\rho}} m^{\frac{\nu\rho(1-\alpha)}{\alpha(1-\nu\rho)}}. \quad (5.53)$$

Plugging this back into equation (5.52) gives the production standard implemented at stage m as a function of parameters, $q(\omega)$, and A as

$$s(m) = \left(\frac{1 - \beta}{c_s} \nu\rho \right)^{\frac{1}{1-\nu\rho}} \left(\frac{1 - \nu\rho}{1 - \alpha} \right)^{\frac{\nu\rho-\alpha}{\alpha(1-\nu\rho)}} q(\omega)^{\frac{\rho}{1-\nu\rho}} A^{\frac{1-\rho}{1-\nu\rho}} m^{\frac{\nu\rho-\alpha}{\alpha(1-\nu\rho)}}, \quad (5.54)$$

analogous to equation (5.14) in the baseline model.

To choose the optimal scale of production the firm has to solve

$$\max_{q(\omega)} \pi_F \omega = \beta r(\omega) - c_x q(\omega) - f. \quad (5.55)$$

Using equation (5.53) evaluated at $m = 1$, the solution to the maximization problem yields

$$q(\omega) = \left(\frac{1 - \nu\rho}{1 - \alpha} \right)^{\frac{\nu\rho(1-\alpha)}{\alpha[1-\rho(1+\nu)]}} \left(\frac{1 - \beta}{c_s} \nu\rho \right)^{\frac{\nu\rho}{1-\rho(1+\nu)}} \left[A^{1-\rho} \left(\frac{\beta}{c_x} \frac{\rho}{1 - \nu\rho} \right)^{1-\nu\rho} \right]^{\frac{1}{1-\rho(1+\nu)}}, \quad (5.56)$$

analogous to equation (5.17).

Turning to the industry equilibrium, using equation (5.53) evaluated at $m = 1$ as well as equation (5.56) in equation (5.55) and setting it to zero gives a first expression for the price index, analogous to

equation (5.19) as

$$P = \left(\frac{f}{1 - \rho(1 + \nu)} \right)^{\frac{1 - \rho(1 + \nu)}{\rho}} \frac{c_x}{\rho} \left(\frac{c_s}{(1 - \beta)\nu\rho} \right)^\nu E^{-\frac{1 - \rho}{\rho}} \beta^{-\frac{1 - \nu\rho}{\rho}} (1 - \alpha)^{\frac{1 - \nu\rho}{\rho}} \left(\frac{1 - \alpha}{1 - \nu\rho} \right)^{\frac{\nu\rho - \alpha}{\alpha\rho}}. \quad (5.57)$$

We can use this result to calculate the values of $q(\omega)$ and $s(m)$ in industry equilibrium using equations (5.56) and (5.54).

$$q(\omega) = \frac{\rho}{c_x} \frac{f}{1 - \rho(1 + \nu)} \quad (5.58)$$

$$s(m) = \frac{1 - \alpha}{\beta} \frac{(1 - \beta)\nu\rho}{c_s} \frac{f}{1 - \rho(1 + \nu)} m^{\frac{\nu\rho - \alpha}{\alpha(1 - \nu\rho)}} \quad (5.59)$$

The above equilibrium expression for $q(\omega)$ shows that $q(\omega)$ remains positive for a larger range of values for ρ . More precisely, while in the case of $\nu = 1$, we had to impose $\rho < 1/2$, we can now impose a weaker condition, $\rho < 1/(1 + \nu)$. As ν grows arbitrarily close to zero, the upper bound of the admissible range for ρ approaches unity. The equilibrium expression for $s(m)$ shows that our main result continues to hold also in this extended version. For our model to predict an upward sloping profile of CSR along the value chain, we need to assume that $\alpha < \nu\rho$.

The remaining equilibrium variables can be calculated as follows. Using the definition of $\varepsilon(\omega)$ we then get

$$\varepsilon(\omega) = \left(\int_0^1 s(m)^\alpha dj \right)^{\frac{1}{\alpha}} = \frac{1 - \alpha}{\beta} \frac{(1 - \beta)\nu\rho}{c_s} \frac{f}{1 - \rho(1 + \nu)} \left(\frac{1 - \nu\rho}{1 - \alpha} \right)^{\frac{1}{\alpha}}. \quad (5.60)$$

Plugging this, the solution for $q(\omega)$ as well as the expression for P into inverse demand gives the pricing rule as

$$p(\omega) = A^{1 - \rho} q(\omega)^{-(1 - \rho)} \varepsilon^{\nu\rho} = \frac{c_x}{\rho} \frac{1 - \nu\rho}{\beta} \quad (5.61)$$

Using $\varepsilon(\omega)$ and $p(\omega)$ in the definition of the price index from demand, $P^{-\frac{\rho}{1 - \rho}} = \int_0^n \left(\frac{\varepsilon(\omega)^\nu}{p(\omega)} \right)^{\frac{\rho}{1 - \rho}} d\omega$, gives a second expression for the price index as a function of the number of firms, n . Combining the two expressions gives the equilibrium number of firms as

$$n = \frac{\beta E}{1 - \nu\rho} \frac{1 - \rho(1 + \nu)}{f}. \quad (5.62)$$

5.5.3.2 Complete Contracts

In the case of complete contracts, we can state the firm's problem analogous to equation (5.35) as

$$\max_{\tilde{q}(\omega), \{\tilde{s}(j)\}_{j \in [0, 1]}} \tilde{\pi}_F(\omega) = \tilde{q}(\omega)^\rho \tilde{A}^{1 - \rho} \left(\int_0^1 \tilde{s}(j)^\alpha dj \right)^{\frac{\nu\rho}{\alpha}} - c_x \tilde{q}(\omega) - c_s \int_0^1 \tilde{s}(j) dj - f, \quad (5.63)$$

with the only difference being the parameter ν attached to ethical quality. Following steps analogous to those outlined in Appendix 5.5.2 gives the following results in industry equilibrium. The production standard $\tilde{s}(j) = \tilde{s} \forall j$ is given by

$$\tilde{s} = \frac{\nu\rho}{c_s} \frac{f}{1 - \rho(1 + \nu)}. \quad (5.64)$$

Because \tilde{s} is identical across stages, it also holds that $\tilde{\varepsilon}(\omega) = \tilde{s}$. The optimal quantity of final good production is given by

$$\tilde{q}(\omega) = \frac{\rho}{c_x} \frac{f}{1 - \rho(1 + \nu)}, \quad (5.65)$$

while the optimal price is given by

$$\tilde{p}(\omega) = \frac{c_x}{\rho} \quad (5.66)$$

and the equilibrium number of firms is given by

$$\tilde{n} = [1 - \rho(1 + \nu)] \frac{E}{f}. \quad (5.67)$$

5.6 Empirical Appendix

This section provides details on two control variables, namely, the measure of wages and the measure of export exposure to OECD countries.

5.6.1 Wages:

We control for the possibility that wages vary systematically with the value chain position. In Prowess, the wage bill is available for a subset of firms. However, there are many zeros and the provision of the number of employees is not compulsory for firms so that we cannot compute wages per employee. We therefore decide not to include the wage bill from the firm-level data and prefer to use a proxy for hourly wages taken from WIOD. We take the hourly compensation paid in Indian industries from WIOD and use the product-level information of firms to generate a firm-level control variable that is similar in spirit to our firm-level upstreamness measure. To this end, we calculate *Wages* as an industry's average hourly compensation to employees weighted by a firm's product sales in the respective industry and year. This delivers our control variable of interest, which is computed in the following way:

$$Wages_{ft} = \sum_{v=1}^V \frac{sales_{fvt}}{sales_{ft}} compensation_{vt}. \quad (5.68)$$

We thus compute *Wages_{ft}* taking industry *v*'s average hourly compensation to employees in year *t* and weighting it with a firm's product sales in the respective industry. Splitting the analyzed sample by the median value chain position shows a median wage level of 24.77 Rupees for the more upstream firms and of 21.65 Rupees for the more downstream firms. However, this does not control for other firm characteristics.

5.6.2 OECD export exposure:

The Prowess data do not cover information on the export destinations of firms. In order to control for heterogeneity in destination markets, we construct a proxy for *exposure to OECD markets* based on information taken from WIOD. This measure is constructed similar to our upstreamness and wage

measures based on WIOD industry data as

$$OECD_export_exposure_{ft} = \sum_{v=1}^V \frac{sales_{fvt}}{sales_{ft}} \frac{exports_OECD_{vt}}{exports_total_{vt}}, \quad (5.69)$$

where we take an industry v 's exports to OECD countries relative to industry v 's total exports in year t and weight this according to a firm's product portfolio.

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Erklärung zum selbständigen Verfassen der Arbeit und Einhaltung der DFG-Richtlinien

Erklärung zum selbständigen Verfassen der Arbeit

Ich erkläre hiermit, dass ich meine Doktorarbeit “Closer and greener? Firms’ global value chain participation and sustainability” selbstständig und ohne fremde Hilfe angefertigt habe und dass ich als Koautor maßgeblich zu den weiteren Fachartikeln beigetragen habe. Alle von anderen Autoren wörtlich übernommenen Stellen, wie auch die sich an die Gedanken anderer Autoren eng anlehrenden Ausführungen der aufgeführten Beiträge wurden besonders gekennzeichnet und die Quellen nach den mir angegebenen Richtlinien zitiert.

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Alle Autoren und Autorinnen haben einen wesentlichen Beitrag zu der wissenschaftlichen Veröffentlichung geleistet. Alle Autoren und Autorinnen haben zu allen Kapiteln einen wesentlichen Anteil geleistet.

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And I would walk 500 miles. And I would roll 500 more. The lyrics of the Proclaimers song capture many of my feelings during the time writing this dissertation. The key feeling might be the happiness of the song which feels somehow naive given that this is around walking distance between the Kiel Institute and Freiburg. Difficult to imagine that you can keep all your positivity if you know that you are walking such a distance. Especially, once you arrive in Freiburg, you realise that you have to roll around 805 km more. Looking at the map, the way back is even worse, you have to roll up. However, I think I can say that I managed somehow to keep the motivation and a positive attitude over the complete distance. Thinking back on the last years, without a doubt, has not been possible without the support of great friends, my colleagues (some even got best friends) and family. With this acknowledgement, I try to name all of them, however, I am sure the list will be incomplete and I am very sorry for that.

Let me first go back in time before I started working as a doctoral student at the Kiel Institute in October 2016. The year is 2009 and I am aware that deciding what to study is a crossroads. In the end, I have two opposing options: Oceanography in Hamburg or Economics in Kiel. Even though I love the sea and it sounds counter-intuitive, I made the right decision. During this time, I was obsessed with understanding the mechanisms behind economics, which affect all of our lives and led to the financial crisis just last year. Compared to the great field trips you can go on while studying oceanography, this sounds lame even to me. But the basic confidence that I could do some good by understanding how the economy works motivated me. I had no idea what that meant.

The eye-opening moment was together with Claas Schneiderheinze around 2011. We both read the book "The Bottom Billion" by Jeffrey Sachs, which was part of a great discussion with William Easterly on how to alleviate global poverty. From that point on, we became immersed in the development economics literature. Now Claas is a colleague at the Kiel Institute, I was his best man at his wedding to Marion and he was my best man at my wedding to Nicola. When Rainer Thiele advertised a position at the Kiel Institute in 2012 in his lecture on development economics, I applied directly. The job interview was warm and inviting. This positive atmosphere continued over the next few years, during which I worked with Marcus Böhme, Tobias Heidland, Toman Barsbai, Linda Kleemann, Kacana Khadjavi, Esther Ademmer, Fred Goretzko and Christiane Gebühr. They all helped me to take my first steps as an economist. Rainer supervised my Master's thesis and an updated version of one chapter of it was even my first publication in a peer-reviewed journal. This support is already far from normal, but in addition, he enabled me to spend three months at the UFRJ in Rio de Janeiro in 2015.

At the end of my Master's degree, I worked as an intern at the GFA Consulting Group and learned how to apply my (quantitative) knowledge as a practitioner in development cooperation. Linda and Tobias asked me to participate in the scientific monitoring of household surveys in ten developing countries. A challenging task and not usual in German development cooperation at that time and on that scale. I learned a lot from the team and even got the opportunity to apply what I had learned to an upcoming data collection in Western Kenya. I will never forget the first moment on a boda boda and the view of Lake Victoria. It is definitive proof that working as an economist is not necessarily lame and the job I want to do.

When a position was advertised at the Kiel Centre for Globalization dealing with the interface of

global value chains and ecological and social consequences, it was immediately clear to me that I wanted to return to the Kiel Institute. I am grateful to Sonja Peterson, who wrote me a letter of reference and supported my application. It is outstanding that there were only women in my job interview, including my two supervisors Aoife Hanley and Katrin Rehdanz. Again, I felt comfortable from the first moment, even though the team was largely new to me. At this stage, it paid off that I besides development economics also specialised in environmental economics during my master's degree. The link between environment and development continued to be a big motivation for my research. Social development is not possible without success in combating climate change. A key to sustainable development is the diffusion of knowledge and technology throughout the world. With my dissertation, I am trying my best to contribute to this understanding.

I will summarise my time a little faster at this point because it fits with the feeling that time has flown by. Without a doubt, my two supervisors Aoife Hanley and Katrin Rehdanz deserve an extra scoop of thanks and appreciation. Thanks for all the comments and feedback you have given me over the last years.

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A balanced private life with great hobbies, friends and family might be the most important ingredient for the stamina you need in science. I would like to highlight my two sisters Lisa and Indra, my father Jossie, my aunt Guni and my grandfather Gerd. They all kept me grounded, which is perhaps due to living on the quiet and pleasant west coast of Schleswig-Holstein. A very special thank goes to my wife Nicola Posniak. We met right at the beginning of our studies, which alone is enough to determine that I made the right decision to study economics. Since then, we have supported each other in all areas, including discussions about our professions. You gave me strength over all the years and your view from a business perspective is always enlightening for my research. Furthermore, we share an interest

in sports, especially kitesurfing and running. Together, this gives us the right balance to keep our heads up whatever life throws at us. It's great to have you by my side. Indeed, life is not always on the bright side and I would like to dedicate part of this work to Moritz Bothe, Martin Grimm, my grandma Christa and my mother Carmen. My memories are still very much alive, even though it is hard to accept that you cannot celebrate the completion of this milestone with me.

Where do I stand now? Honestly, I still don't think I understand all facets of economics. So I will continue on my path as an economist and just walk another 500 miles.