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EXPORTING POLLUTION

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ABSTRACT

Despite awareness of the detrimental impact of CO_2 pollution on the world climate, countries vary widely in how they design and enforce environmental laws. Using novel micro data about firms' CO_2 emissions across countries, we document that firms headquartered in countries with strict environmental policies perform their polluting activities abroad in countries with relatively weaker policies. These effects are stronger for firms in pollution-intensive industries and firms with poor corporate governance characteristics. Although firms with domestic strict environmental policies are more likely to export pollution to foreign countries, they nevertheless emit less overall CO_2 globally.

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1 Introduction

In recent years, countries have increased the strictness and enforcement of environmental policies following general consensus that greenhouse gases from industrial production are the primary cause of global warming. Yet, countries vary greatly in how they design and implement environmental laws (United Nations Global Environment Outlook, 2019). This diversity in policies across countries can lead to "carbon leakage," meaning that firms decide strategically where to locate their production, and consequently, where they will emit greenhouse gases. In addition, because countries benefit from industrial production (e.g., through employment), some may design their environmental policies to attract industrial production by multinationals or at least provide economic incentives to retain the industrial activity of domestic firms.[1] While prior studies have attempted to examine the effects of environmental regulations on pollution at the aggregate level or within countries (e.g., Ederington, Levinson, and Minier, 2005; Bento, Freedman, and Lang, 2015; Bartram, Hou, and Kim, 2018), little is known about the extent to which firms allocate polluting activities around the globe. Understanding the symbiotic relationship between countries' environmental policies and the production decisions by multinational firms is critical to effectively addressing the emerging challenges from climate change.

In this paper, we describe the equilibrium outcome of pollution activities by multinational firms at home and in foreign countries in the 2010s in relation to countries' environmental policies.[2] The study is based on a unique panel dataset covering 1,970 large public firms headquartered in 48 countries and their carbon dioxide (CO_2)[3] emissions in 218 countries during the 2008-2015 period. The goal of this study is two-fold. First, we study the relation between the environmental policies of individual countries and global pollution by firms headquartered in these countries. We further explore how differences in countries' environmental policies are related to the geographic allocation of pollution by multinational firms around the globe. Second, we study

[1] For example, European countries provide incentives to industries that have competitive pressure to transfer their polluting activities to foreign countries: https://ec.europa.eu/clima/policies/ets/allowances/leakage_en.

[2] Other studies, such as Kim, Wan, Wang, and Yang (2019), explore the causal relationship between changes in environmental policies and firm response. Due to constraints related to tight identification, these studies tend to focus on specific episodes and therefore have limited geographical and temporal scope.

[3] Although several greenhouse gases contribute to climate change, we focus on CO_2, which is a byproduct of industrial production and has the fastest concentration growth in the atmosphere. For further information, see https://www.ucsusa.org/global-warming/science-and-impacts/science/CO2-and-global-warming-faq.html.

the cross-section of multinational firms, i.e., differences among industries and governance structures. The unique feature of our dataset is that we can separately observe the CO_2 emissions of each multinational firm in *each country* in which it operates. This feature of the data allows us to provide direct evidence on the relation between environmental policies and firms' actual CO_2 emissions at the micro-level.

A combination of both demand and supply effects lead multinational firms to transfer polluting industrial activities to countries with weaker environmental policies. From the demand side, firms may export their polluting operations to countries with loose environmental policies because restricting emissions is costly, requiring investment in resources such as waste treatment, auditing, and litigation (see, e.g., Christainsen and Haveman, 1981; Stewart, 1993). From the supply side, countries may deliberately impose relatively weak environmental policies and use lax enforcement to attract polluting firms. Such countries can benefit, at least in the short run, from the economic growth (e.g., employment, investments) that additional industrial production would bring.

Our study has two parts. In the first set of analyses, we explore the location of pollution activities with respect to countries' environmental policies. Using a firm-year panel, we document that firms headquartered in countries with stricter environmental policies emit less CO_2 both domestically and globally. However, we find evidence of carbon leakage from countries with strict environmental policies. Specifically, stricter domestic environmental policies are associated with a greater share and greater amounts of pollution abroad. The effects are economically large: A one-standard deviation increase in the strictness of environmental policies in the home country is associated with about 15% lower global CO_2 emissions overall. Furthermore, a one-standard deviation increase in the strictness of environmental policies is associated with up to a 29% decrease in emissions at home, and up to a 43% increase in emissions abroad. These results lend support to the concern of countries that strict environmental policies may lead to carbon leakage, i.e., transfer of polluting activities to foreign countries with lax environmental policies. While strict national environmental policies are effective in reducing global CO_2 emissions to a certain extent, they also create negative externalities, incentivizing firms to export their polluting activities to other countries.

Next, we explore the destination countries to which firms export their pollution. Specifically, we test the prediction that the “distance” in policy strictness between home and foreign country can predict whether and the extent to which such exporting takes place. Using a firm-country-year panel, we examine whether the relative strictness of environmental policies in the home country versus the foreign country is correlated with more pollution abroad. We document that firms pollute more in a foreign country when the gap in the strictness in environmental policies between the home and foreign countries is greater.

In the second part of the study, we examine the factors that amplify the incentives of firms to pollute abroad in response to strict environmental policies at home by exploiting the cross-section of firms. We first consider firm-level governance. For firms that are considered to have strong governance, we find that the positive effect of strict regulations on pollution is more pronounced. In other words, when the home country sets strict environmental policies, well-governed firms produce fewer emissions domestically and export fewer emissions to foreign countries. Importantly, this result could imply that firms face a tradeoff between polluting and long-term firm value. Managers may prefer to engage in polluting production and not costly clean production in order to achieve financial goals in the short run (see Krueger, 2015, as well as the Dupont case in Shapira and Zingales, 2017). However, strong governance mechanisms guide managers to consider the long-term value generation and therefore counterweight towards production with lower emissions. The pressure to implement sustainable production techniques is generally associated with long-term investors who value corporate responsibility practices (see, e.g., the survey regarding the institutional investors’ perceptions of climate risks in Krueger, Sautner, and Starks, 2018, and Bonnefon, Landier, Sastry, and Thesmar, 2019).[4]

Since there is large heterogeneity across industries, we conduct further analysis in the cross-section of industries. In particular, we examine the importance of industry-level pollution intensity. We identify the pollution-intensive industries based on the CO_2 emission per unit of gross value added at the industry level. We document that firms’ behavior with respect to environmental policies is more accentuated when they are part of pollution-intensive industries. Firms in pollution-intensive industries do not reduce emissions at home in response to strict home

[4] Consistent with institutional investors valuing firm environmental profiles, Kim, Wan, Wang, and Yang (2019) empirically document that firms mostly held by investors with socially responsible investing (SRI) styles tend to adopt environment-friendly corporate policies and eventually release fewer toxic chemicals.

regulations while the rest of firms significantly decrease home emissions. In addition, firms in pollution-intensive industries export emissions to foreign countries twice as much as the average firms in other industries do. This finding is consistent with the idea that complying with strict environmental policies is costly for pollution-intensive industry firms, causing them to perform their CO_2 emissions abroad. Our results imply that policymakers might have a greater impact on reducing global emissions if they target these high-polluting industries, which in turn will have also immediate implications for companies and managers.

Overall, our findings on multinational firms' CO_2 emission patterns in response to the stringency of different countries' environmental policies highlight the need for global coordination of regulations regarding carbon dioxide emissions. Our results imply that multinational firms with production facilities around the globe may continue to benefit from regulatory arbitrage opportunities by exporting pollution. At the same time, this study emphasizes that local policies restricting pollution activities do have some effect on reducing global pollution levels.

Our study informs the debate among environmental economists about the effectiveness of environmental policies in reducing pollution (e.g., Eskeland and Harrison, 2003; Cole, 2004, among many others). The pollution haven hypothesis, a prominent theory in the literature, posits that individual countries' strict environmental policies have little impact on global pollution levels, as corporations will simply shift polluting activities to countries with more lenient environmental policies (see, e.g., Hambel, Kraft, and Schwartz, 2018). Consistent with this hypothesis, we find that corporations indeed shift polluting activities to foreign countries with less stringent environmental policies. However, our results also show that firms headquartered in countries with strict environmental policies pollute less overall.

To the best of our knowledge, this study is the first to use micro-level data to provide direct evidence of the symbiotic relationship of countries' environmental policies and the actual pollution taking place by multinational firms in these countries. Previous studies estimate whether firms are more likely to have facilities in countries with weak environmental policies *without* observing actual pollution levels (Becker and Henderson, 2000, 2001; Dam and Scholtens, 2012; Ben Kheder and Zugravu, 2012). Furthermore, prior work on the impact of environmental policies on pollution generally uses indirect and high-level proxies for environmental regulations and pollution data aggregated at the industry- or country-level. Several studies correlate aggregate industrial activity and the stringency of environmental laws in home countries compared to target countries (Shafik and Bandyopadhyay, 1992; List, 2001; Cole and Elliott, 2005; MacDermott, 2009; Wagner and Timmins, 2009; Kalamova and Johnstone, 2011; Ben Kheder and Zugravu, 2012). Many of these studies are not able to observe environmental regulation and thus use country-level proxies for the stringency of regulation, such as pollution abatement costs. In this study, we use unique data on the actual CO_2 emission by firms and directly link the stringency in environmental policies of more than 200 countries to firm-level CO_2 emissions. Our analysis complements previous findings and imply that firms have incentives to relocate their production to countries with more lax environmental regulations to circumvent expensive pollution controls in their home country.

Our study also contributes to the growing literature on corporate social responsibility. Recent papers focus on firms' environmental policies and the extent to which firms' compliance with environmental standards are recognized by shareholders. For example, Dowell, Hart, and Yeung (2000) find that firms that comply with globally strict environmental standards have higher Tobin's Q ratios than those that only adopt local standards. Chava (2014) documents that firms that emit substantial amounts of hazardous and toxic chemicals pay a higher cost of equity and debt capital than those without such environmental concerns. Given this evidence that environmental policies can affect firm value, several recent studies have attempted to identify determinants of firms' polluting behaviors. For example, Kim, Wan, Wang, and Yang (2019) find that long-term investors actively work to improve firms' environmental policies, leading to lower emissions of toxic chemicals. Financial constraints are also known to exacerbate firms' incentives to pollute (Levine, Lin, Wang, and Xie, 2018; Shive and Forster, 2019; Kim and Xu, 2018; and Bartram, Hou, and Kim, 2018). Our paper adds to this strand of the literature by providing evidence on the importance of operating locations in understanding firms' polluting incentives. When firms face tight environmental regulations at home, they are more likely to export pollution to foreign countries. More importantly, our cross-section results suggest that strong firm-level governance can mitigate these negative externalities associated with strict national regulations.

2 Data Description

2.1 CO_2 Emissions Data

Our main data source is a large database provided by CDP (formerly known as the Carbon Disclosure Project) that contains firms' self-reported survey responses about their national and global CO_2 emissions. CDP is a UK-based "not-for-profit charity that runs the global disclosure system for investors, firms, cities, states, and regions to manage their environmental impacts" (CDP, 2017). As of 2017, more than 800 institutional investors with US$100 trillion in assets under management (AUM) were supporting the CDP and its initiatives. Since CDP's inception, the number of institutional investors that have become signatories of CDP has grown tremendously as has the assets under management represented by those investors. The CDP began by only surveying UK-based FTSE firms but now obtains climate change and pollution information from firms around the world.

Our dataset consists of annual survey data from firms between 2008 and 2015. Over this period, CDP increased its outreach from about 3,000 to more than 6,000 firms worldwide. CDP sends its survey to the largest firms in the world, most of which have publicly-traded equity. The questionnaires ask firms about their CO_2 emissions, their various approaches to combatting climate change, and the practices they use to manage potential risks stemming from climate change. In this study, we focus on the questions that ask firms about CO_2 emissions both directly and indirectly from their operations. The answers to these questions allow us to directly measure firm-level emissions and identify the countries in which these emissions take place. Overall, the firms in our sample emit CO_2 in 218 different countries. We have pollution information on firms that operate in multiple countries as well as firms that operate in a single country (about 11% of the sample). We create a panel dataset containing annual CO_2 emissions information for firms in each country in which they operate.

We have two measures of CO_2 emissions: Scope 1 and Scope 2. Scope 1 emissions are the total CO_2 emissions (in metric tons) that stem directly from the operations of the reporting firms. Scope 2 emissions are the total CO_2 emissions arising from the production of the electricity the firm purchases to run its operations and over which it does not have direct influence. The firm estimates this quantity based on a breakdown of the electricity sources used in the respective country. Hence, Scope 2 measures, in metric tons, emissions that take place upstream in the supply chain.

Note that our data are based on firms' self-reported information. Specifically, the CDP collects data that firms voluntarily provide in response to a survey. Despite the self-reported nature of our data, we believe that the emissions information is accurate and close to actual emissions for several reasons. First, firms' incentive to report their emissions comes from pressures from both institutional investors and regulators who demand greater transparency about the environmental impacts of their business and how climate change affects the long-run viability of the business. Investors, especially long-term institutional investors such as pension funds and insurance companies, seek understanding the long-run implications of tightening climate change and environmental regulations resulting from the Paris Agreement on climate change, which was agreed upon in 2015 and subsequently has been implemented by most signatory countries. In addition, institutional investors are interested in learning about firms' exposure to climate change and environmental issues to identify business models that are at risk or less resilient. The consequences of misreporting can be detrimental for multinational firms, which rely on institutional investment. Second, prior research shows that firms report emissions rates that are at least as high in their sustainability reports (like CDP) as in their annual financial reports (Depoers, Jeanjean, and Jérôme, 2016). Finally, a self-reporting bias is likely to attenuate results *against* finding supporting evidence that firms in tightly regulated countries are more likely to export pollution. Firms might under-report their emissions activity in foreign countries. If anything, our results are likely to show a lower bound for the effect, because pollution reporting is voluntary and the reporting firms may be less aggressive than non-reporters.

To address the concern that self-reporting may affect our results, we repeat some of the tests using a subset of firms that report audited data. Specifically, investors of some firms have begun requiring their auditors to approve the statistics in the sustainability reports. We have information on whether firms had their auditors verify the CO_2 information and which reporting standard they applied.[5] We use this fact to provide some assurance regarding the quality of the data and hence the results in Section 4.2.[6]

2.2 Environmental Laws and Enforcement Data

We use an additional dataset which contains information about the strictness of environmental laws and enforcement at the country-year level. We use a dataset compiled by the World Economic Forum (WEF) that covers the 2008-2015 period and is publicly available on a bi-annual basis for 150 countries.[7] WEF assigns two rankings for each country on a scale from 1 to 7: (1) the stringency of their environmental regulation (SER) and (2) how strictly these laws are enforced (EER), based on surveys of top local business leaders.[8] The correspondent profile of the survey increases the validity of our results, because the WEF measure reflects scores as perceived by corporate leaders, who eventually respond to this perception by determining the location of polluting activities. The two environmental policy measures—stringency of environmental regulation and stringency of enforcement—are highly correlated (correlation coefficient of 0.97).

For the practical purpose of our analysis we combine the two policy measures to a single measure. We assume that a country needs both components, laws and enforcement, to have a robust environmental policy in place. Stated differently, an inherent interaction exists between these two dimensions: Strict environmental laws must be enforced to make a difference. Because of the high

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[5] The CDP data contain information on how and to what extent the firms' auditors or other third parties have verified the reported carbon emissions. The dataset also contains information about what reporting standard or framework was applied to verify the carbon emissions, such as, for example, ISO14064-3. Furthermore, companies usually disclose in their annual reports or sustainability reports whether the reported information on carbon emissions therein has been verified and, if so, by whom.

[6] When we restrict the sample to those observations for which the emissions information has been verified by external parties such as the firms' auditors, the main results are quantitatively similar to those we obtain using the full sample. We discuss these robustness tests and results in Section 4.2.

[7] See Travel & Tourism Competitiveness Reports of WEF, e.g., https://www.weforum.org/reports/the-travel-tourism-competitiveness-report-2017.

[8] We use annual rankings from the WEF's Executive Opinion Survey administered to more than 14,000 business leaders worldwide. Two survey questions are relevant to our study: (1) How would you assess the stringency of your country's environmental regulations? and (2) How would you assess the enforcement of environmental regulations in your country? Answers range from 1 (very lax) to 7 (among the world's most rigorous). According to the WEF, its survey "captures the opinions of business leaders around the world on a broad range of topics for which data sources are scarce or, frequently, nonexistent on a global scale. It helps to capture aspects of a particular domain … that are more qualitative than hard data can provide" (Schwab and Sala-i-Martin, 2016). The WEF survey measures are highly correlated with policy-based indices such as the EBRD's CLIMI index or the OECD's EPS index (Botta and Koźluk, 2014) but have the advantage of being available for a large number of countries over time.

correlation of these variables, introducing both into the regression simultaneously induces severe multicollinearity. To remedy this issue, we adopt three approaches. The first is to combine the two scores into a single variable: $SEER = \frac{1}{7} SER * EER$. We call this measure stringency and enforcement of environmental regulation, or *SEER*, and its value ranges from 0 to 7. The other two approaches involve examining the effect of each variable in isolation and orthogonalizing the variables so that we can introduce both into the regressions. We implement these approaches as a robustness test in Section 4.1. Overall, our results largely remain robust across the three methods.

2.3 Firm-level Financial Data

We obtain financial information about multinational firms and the countries in which they operate from commonly-used databases. We use firm-specific financial statement data from Worldscope and country-specific macro-economic data from the World Bank's World Development Indicators. We also collect country-pair proxies such as geographical distance, common border, colonial history, and logged annual trade between the firm's home country and the country in which it emits CO_2. These proxies come from distancefromto.net, Andrew Rose's website (see Glick and Rose, 2016), and the IMF's Direction of Trade Statistics. Finally, as our measure of the corporate governance quality of firms, we use the corporate governance score provided in the Thomson Reuters Asset4 database (*CGVSCORE*). Thomson Reuters Asset4 is firm-year dataset widely-used in academic research as well as by long-term institutional investors interested in environmental, social and governance (ESG) information. The governance score ranges from 0 to 100 and measures as a percentage the quality of a firm's governance systems and processes, ranging from board structure and compensation arrangements to a firm's treatment of shareholder rights. A higher *CGVSCORE* value indicates better governance. Variable definitions and sources can be found in Appendix Table 1.

The final dataset that we construct is a three-dimensional panel of the firm-country-year that contains the amount of CO_2 emissions by each firm in each country in each year. Naturally, most of our emissions observations have a value of zero, because firms tend to have operations in a limited set of countries.[9]

2.4 Summary Statistics

2.4.1 Pollution and Environmental Regulation over Time

Table 1 reports summary statistics over the sample period of 2008 to 2015, including the number of unique firms, their global and home-country emissions, and the number of countries in which each firm has emissions. For the average firm, global emissions in tons decrease over time for Scope 1 and 2. Note that the majority of emissions arise from the direct Scope 1 emissions. One caveat of interpreting the average firm-year emissions, however, is that these trends can be a result of the expanding coverage of firms by CDP (see Section 3.3, for a discussion of time trends of emissions). Most CO_2 is emitted domestically, but the share of home emissions in global emissions decreases substantially over time (from 72% to about 57% for Scope 1 emissions). In addition, the number of countries where the average firm's emissions take place increases from 6.0 (6.8) countries in 2008 to 9.0 (10.6) in 2015 for Scope 1 (Scope 2).

As described earlier, our measure of environmental regulation is SEER, which is the product of measures of the environmental strictness score (ranging from 0 to 7) and the environmental enforcement score (ranging from 0 to 7), scaled by 7. Panel C of Table 1 indicates that SEER generally increases over time, both on average and at the median, with most of the improvement occurring among the 50 countries that had the weakest environmental policies in 2008. This finding suggests that environmental regulation tightens over time. Furthermore, we observe that the distribution of environmental regulation is skewed, with most countries being weakly regulated.

Environmental regulation varies greatly across the globe. Figure 1 uses heat maps to show country-level environmental regulation at the beginning and end of our sample period. The map shows a general improvement in environmental regulation over time; however, environmental regulation remains weak in several large regions, especially in developing countries in Africa,

[9] Not all firms fully disaggregate their global emissions to the country level. We thus impose a minimum disaggregation requirement and restrict our sample to firms that report at least 85% of their global emissions on a country level.

South America, and Asia. This relative stability of environmental regulation gaps across countries implies that our empirical analyses will provide micro-evidence for the equilibrium outcome rather than identifying demand and supply effects. Our results will be driven primarily by cross-sectional variations in environmental regulation across countries rather than the response of firms to substantial changes in national regulations.

Figure 2 presents a visualization of the relationship between environmental regulation in the firm's home country (as measured by our proxy SEER) and firm-level emissions abroad. We plot each country as a circle, the size of which represents the average home emissions by firms in that country (in tons). The color of the circle indicates the stringency of environmental regulation scores (SEER) in the home country, with the scale from red (the weakest regulation) to green (the most stringent regulation). The y-axis shows the average percentage of emissions in foreign countries. Two observations can be made. First, the size of the circles is much smaller in green countries than in red countries, suggesting that strict regulations in home countries are negatively associated with the amount of home emissions. Second, the slope of the dotted predictive line implies that firms located in strictly-regulated countries produce a higher proportion of their CO_2 emissions abroad than domestically.

2.4.2 Firm-level Summary Statistics

Table 2 presents summary statistics for our sample firms. It shows that, on average, firms emit more in their home countries than abroad (1.85 million tons vs. 1.30 million tons for Scope 1 emissions and 0.37 million tons vs. 0.30 million tons for Scope 2 emissions). On average, 38.3% (42.8%) of firms' Scope 1 (Scope 2) emissions are emitted abroad. These ratios are slightly higher at 41.4% for Scope 1 (44.8% for Scope 2) when we take the value-weighted average, using the amount of global emissions as weights. The average SEER for a firm in our sample is 4.11; the average score for the strictness of environmental regulation is 5.43; and the average score for the enforcement of environmental regulation is only 5.23. The firms covered in our sample are mostly large multinational firms with an average of US$60.7 million in assets and a foreign asset share of 26.4%. Panel B of Table 2 provides additional country-level statistics that we use in our empirical analyses as control variables.

3 Empirical Design and Results

3.1 Polluting Domestically or Abroad?

To test whether firms pollute more in countries with weak environmental policies, that is, those with low SEER scores, we use the following dependent variables to explore the determinants of polluting location: logged global emissions of CO_2, logged emissions in the home country, logged total emissions in all foreign countries, and total foreign emissions as a percentage of global emissions.[10] Our main variable of interest is SEER, the combined variable of environmental policy and enforcement strictness in the firm's home country. Other independent variables include logged firm assets, the share of foreign assets, and logged gross domestic product (GDP) in the home country, in addition to year and industry fixed effects. Standard errors are clustered by firm.

The results are presented in Table 3. Panels A and B show evidence for Scope 1 and Scope 2 emissions, respectively. In Columns (1) and (2), we regress logged global emissions in tons on SEER and the control variables. In Panel A, the coefficient on SEER is negative, indicating that firms exposed to strict environmental policies in their home country pollute less globally. A one-standard deviation increase in SEER (0.90) is associated with a 15% decrease in global emissions after controlling for firm size, home-country characteristics, and year and industry fixed effects.[11] The results for Scope 2 emissions in Panel B are of similar magnitude. These effects are not only statistically significant but also economically relevant: For the average firm that emits 3.15 million tons of global Scope 1 CO_2 each year, a 15% reduction amounts to 472,500 tons of CO_2 each year.

The results are robust to different regression specifications. In the regressions presented in Column (2) of Panels A and B of Table 3, we also control for a firm's share of assets that are located abroad. We include this independent variable, which is mainly driven by factors other than environmental regulation, to control for the higher likelihood of foreign emissions when the firm has more assets located abroad for reasons other than environmental regulation, such as labor cost or closeness to customers. Due to the limited availability of the foreign asset share variable, the number of observations in the regressions slightly drops. Our previously documented results remain unchanged, and we find that a firm's share of foreign assets does not influence its global emission levels in either direction.

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[10] We add one to all emissions variables before logging them.

[11] $\%\Delta y = 100 * (e^{\beta * \Delta x} - 1) = 100 * (e^{-0.18 * 0.9} - 1) = -14.96\%$.

Overall, these results do not support the commonly-held view that an individual country's strict environmental policies have little association on global pollution levels. Instead, we document that firms headquartered in highly-regulated countries pollute less globally, potentially due to the environmental standards imposed by the home country.

We next test whether the strictness of home-country regulations is related to the geographic allocation of pollution activities. We explore the emissions in logged tons of CO_2 at home versus abroad in Columns (3)-(4) and (5)-(6), respectively, of Table 3. Because some firms have zero emissions in their home countries, we use a Tobit model for this specification.[12] Here the effect is larger: A one-standard deviation increase in SEER is associated with up to a 29% decrease in emissions at home.[13] By contrast, a one-standard deviation increase in the strictness of environmental policies at home is associated with up to a 43% increase in emissions abroad.[14] As for Scope 2 emissions, Panel B shows that a one-standard deviation increase in SEER is correlated with a 54% decrease in local emissions and a 45% increase in foreign emissions.[15] For both Scope 1 and Scope 2 emissions at home, we find that a higher foreign asset share significantly reduces a firm's emissions at home; however, this effect does not cancel out the influence of countrywide environmental legislation and enforcement. Our results can be interpreted in the context of Walker (2011), who shows that stricter environmental regulation in the U.S. in form of the Clean Air Act leads to plant-level downsizings and ultimately lower sector-level employment. Lower production at home rather than investment in green technology might thus be responsible for at least part of the reduced home country emissions.

In Columns (7) to (8), we reaffirm the previous findings by documenting the relation between environmental regulation and foreign emissions as a percentage share of total global emissions. Specifically, a one-standard deviation increase in the strictness of domestic environmental policies is associated with a 4.1% greater share of foreign emissions.[16] The result for Scope 2, in Panel B, shows a greater corresponding effect of 6.6%.[17] As foreign Scope 1 (2)

[12] Because the fraction of observations that is censored is relatively low in our sample, we re-estimate all Tobit regressions in Tables 3 to 5 and Appendix Tables 3 and 4 as OLS. The results remain similar in the alternative specification, and they can be provided upon request.
[13] From Column (3): $100 * (e^{-0.38 * 0.9} - 1) = -29.0\%$.
[14] From Column (5): $100 * (e^{0.40 * 0.9} - 1) = 43.3\%$.
[15] For Column (3): $100 * (e^{-0.48 * 0.9} - 1) = -54.0\%$; for Column (5): $100 * (e^{0.41 * 0.9} - 1) = 44.6\%$.
[16] $4.54\% * 0.9 = 4.1\%$.
[17] $7.38\% * 0.9 = 6.6\%$.

emissions amount to 38.3% (42.8%) of total global emissions for the average firm in our sample, these effects are substantial and economically meaningful.

Overall, the findings in Table 3 show that firms headquartered in countries with stricter environmental policies emit less CO_2 globally. However, with stricter environmental regulation, the CO_2 emissions at home are significantly lower but foreign emission levels (in absolute and relative terms) are significantly higher. These results imply that while strict environmental policies incentivize firms to allocate polluting activities to countries with weaker environmental policies, we still find that country-level environmental regulations are related to lower global pollution levels.

3.2 Where Do Firms Emit CO_2?

Next we examine in which countries firms perform their pollution. If firms export pollution to foreign countries with weak environmental policies, then one might conclude that the stringency of environmental policy is likely to be an important determinant in firms' decision making and that countries effectively attract industrial activity of foreign multinational firms by offering lax environmental policies. The analysis in this section, therefore, explores whether multinational firms pollute in foreign countries that have weaker or stronger environmental policies than those in their home country. To investigate this issue, we construct a firm-country-year panel and estimate the amount of CO_2 emissions by a firm in a specific country each year. In contrast to the previous specification, which focused on the environmental policies in the home country, the disaggregated model allows us to determine how the "distance" between home and foreign environmental policies is related to the location of emissions. Specifically, we test whether a firm's tendency to transfer polluting activity to a foreign country increases with the gap between the domestic environmental policies and those abroad. Put differently, countries with laxer or less stringently enforced environmental policies may "attract" pollution from firms based in countries with relatively stricter environmental policies.

Figure 3 provides an intuitive visualization of our approach using firm-target country pair level analyses. We focus on the emissions of firm *i* in foreign country *c* in year *t*, and only include the observations for which the SEER in the home and foreign country is known. In addition, we drop the observations of firms with zero emissions in foreign country *c* in year *t* to avoid any potential bias in calculating means from zero-emission observations. The variable of interest is the difference between the SEER of the firm *i*'s home country and the SEER in foreign country *c*. On the x-axis, the left bars represent observations with stronger environmental regulations abroad; the middle bars represent observations with similar environmental regulations at home and abroad; and the right bars represent observations with stronger environmental regulations at home. The y-axis shows tons of CO_2 emissions per GDP of the foreign country, which is averaged across all firm-country-year observations. The chart shows that pollution abroad increases monotonically with the gap in the stringency of environmental policies. In other words, firms emit in foreign countries where the gap in environmental regulation is most favorable to them.

To implement the firm-country-level analyses in a regression setting, we use the following procedure. We create a firm-country-year combination matrix that has a cell for each firm *i* corresponding to each of the 149 foreign target countries *c* in year *t* as long as the firm *i* reports non-zero CO_2 emissions in a given year *t*.[18] In each cell, we record the pollution of the firm in the country during the specific year. Importantly, we also have a cell with a value of zero for firm-country-years in which no activity was recorded. In fact, about 95% of our dataset has zero activity. We drop all cells related to the firm's activity in its home country because our intention is to study the choice of foreign countries to target for pollution.

Our variable of interest is the distance, or *difference* between $SEER_{Home}$ and $SEER_{Foreign}$, the environmental policy scores for the home country and the foreign country, respectively. Positive (negative) values indicate the regulation is stronger (weaker) at home. The higher the value of $SEER_{Home} – SEER_{Foreign}$, the stronger the regulation at home is relative to the foreign country. Note that the home country is a stable firm-level characteristic, whereas the foreign country changes from one cell to another.

Table 4 shows the results of the regressions using the firm-target country-year panel. In each model, we regress either the logged CO_2 emissions (in tons) or the percentage of global emissions the firm emits in the foreign country on the difference in SEER scores between the home and the foreign country. As before, we control for logged firm assets and the share of foreign assets. In addition, we control for the foreign country's GDP and country-pair controls that reflect the

[18] The number of countries in our analysis is limited to 150 countries with the environmental policy scores (SEER) available.

relations between the home and the foreign country: logged geographic distance (in kilometers), whether the countries share a common border, and whether the countries share a colonial history. We also include year, industry, foreign-country, and home-country fixed effects.

In all regressions in Table 4, the coefficients for $SEER_{Home} - SEER_{Foreign}$ are positive and significant. These results indicate that foreign emissions are higher in countries where environmental regulation is weaker than in the firm's home country. The effects are sizable: a one-standard deviation (1.52) increase in the relative strictness of the environmental policies at home compared to abroad is associated with an up to an 84% increase in emissions in the respective foreign country. [19] This finding suggests that firms export pollution to countries where environmental regulation is relatively weaker.

The other control variables have the expected signs: Emissions are higher for larger, more international firms and when countries are geographically closer, trade more with each other, or share a colonial history. The more internationally a firm operates, the higher its foreign emissions. These results make intuitive sense considering that emissions are the direct result of a firm's production or operations.

3.3 Time Trends in CO_2 Emissions

As the environment regulations has tightened globally in recent years, it is important to examine how pollution activities have evolved over time. To understand the trend of the overall amount and allocation of CO_2 emissions by multinational firms in our sample, we estimate the OLS regressions with time fixed effects, using the sample of firm-year emission observations. The dependent variables include the CO_2 emissions variables as in Section 3.1. In addition to year indicators, we include firm fixed effects in the regressions in order to address any potential sample bias from the increase in coverage of firms by CDP. Thus, the coefficients of the year dummy variables would indicate the incremental changes in pollution activities over time (2008 as a baseline) after controlling for any firm-level unobservable factors that might be correlated with being included in the CDP dataset.

[19] From Column (1): $100 * (e^{0.40 * 1.52} - 1) = 83.7\%$; from Column (3): $100 * (e^{0.38 * 1.52} - 1) = 78.2\%$.

In Figure 4, we plot the point estimates and 95% confidence intervals of year indicators for the global, home, and foreign emissions, and the percentage of foreign emissions. In Panel A, we observe a rise in global emissions in 2010 and the global emissions remain relatively constant afterwards. However, the percentage of foreign emissions has been increasing over time. We can confirm such a pattern clearly when focusing on the allocation of pollution between home and foreign countries in Panel B. We find that firms continuously have been increasing exporting pollution to foreign countries from 2008 to 2015 while moderately reducing pollution at home countries. These figures imply that global carbon emissions by firms neither increased nor decreased substantially. However, carbon leakage becomes more prevalent from 2008 until 2015.

3.4 Role of Corporate Governance

Corporate governance could potentially affect how firms respond to a country's environmental policies. Managers of well-governed firms look after the interests of their investors. Traditionally, the interests of investors have been confined to their financial interests; therefore, firms with good corporate governance are expected to minimize costs.[20] As such, if governance is related to the maximization of profits and complying with strict home environmental regulation is costly, we expect that firms with good corporate governance are more likely to shift emissions to foreign countries when home environmental policies are strict.

To explore the role of corporate governance in moderating the correlation between the degree of CO_2 emissions and environmental policies, we interact SEER with a dummy variable indicating good corporate governance practices. The dummy, based on the CGVSCORE from the Asset4 dataset, receives a value of one for a score that is above the annual in-sample median. The CGVSCORE takes into account more than 250 individual governance aspects of the firm in the areas of board structure, compensation policy, board functions, shareholder rights, and strategy.

[20] In recent years, a growing number of institutional investors are also interested in nonfinancial returns, that is, firms should not only look after their financial stakeholders but also other material stakeholder groups that are crucial for the long-term business success of the company. For example, Hermes Investment Management stipulates that its mission is to generate so called "holistic returns, returns that "go far beyond the financial and consider the impact our decisions have on society, the environment and the wider world." (see https://www.hermes-investment.com/ukw/wp-content/uploads/sites/80/2017/07/Hermes-Delivering-Holistic-Returns.pdf, page 1). Also, in 2017, Larry Fink—the CEO of Blackrock, the largest asset management firm—explained in his Annual Letter to CEOs of firms in which Blackrock invests that their firms should not only generate financial returns for their investors but also benefit society (see https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter).

As reported in Panel A of Table 2, the average corporate governance score in our sample is 65.1% and the median is 76.5%.

The corporate governance analysis is presented in Table 5. The regression results show that firms with above-median corporate governance scores are more sensitive to home environmental policies; that is, they emit less in their home country when environmental policies are strict (Column (2)). The results in Panel A indicate that whereas poorly governed firms have higher foreign emissions when home environmental policies are strict, well-governed firms do *not* emit more Scope 1 emissions abroad (the interaction cancels out the main effect; see the F-test in Column (3)). Well-governed firms thus reduce emissions at home while keeping foreign emissions unchanged. This leads to an overall higher percentage share of foreign emissions (the interaction adds to the main effect; F-test for Column (4)), but this effect is mechanical, meaning that it is driven by reduced home emissions but not by increased foreign emissions.

There could be multiple non-mutually exclusive explanations for these effects. First, managers in well-governed firms may have a genuine interest in sacrificing short-term gains for long-term benefits to the firm and its stakeholders (see Shapira and Zingales, 2017, for a case study of pollution by DuPont). Second, well-governed firms may attract investors who care about corporate social responsibility and advocate for such investments. In other words, good corporate governance could be a proxy for a strong shareholder base that pushes such an agenda on corporate social responsibility.

Panel B presents similar results for Scope 2 emissions. Again, well-governed firms are over twice as sensitive to strict environmental policies in the home country as firms with below-median governance scores. As with Scope 1, firms with good corporate governance are less sensitive to environmental policies when deciding on polluting in foreign countries (Column 3) and emit overall a larger fraction of their global emissions abroad (Column 4) than poorly-governed firms.

3.5 Pollution-intensive Industries

We next examine whether firms adjust their behavior with respect to home-country environmental policy differently across industries. We are interested in the pollution-intensive industries, which account for most emissions. The underlying hypothesis in this section is that firms in pollution-intensive industries are more likely to shift their emissions abroad rather than try to minimize them in the home country.

We use a dummy for both firms in industries with high pollution intensity. We base our indicator on the definition used by the European Union (EU),[21] which measures the kilograms of CO_2 emitted in generating one Euro of gross value added. The industry-year table provided by the European Union is presented in Appendix 2, and Figure 5 shows the industry averages in graphical form. The chart clearly shows three groups of polluting industries. The top two industries—electricity, gas, steam and air conditioning supply, and manufacturers of coke and refined petroleum products—emit around 6 kilograms of CO_2 per one Euro of gross value added. The next four industries—air transport, water transport, manufacture of other nonmetallic mineral products, and manufacture of basic metals—emit between 3 and 4 kilograms of CO_2 per one Euro of gross value added. All other industries emit less than 2 kilograms of CO_2 per one Euro of gross value added. Based on these figures, we define pollution-intensive firms as those in the top six polluting industries.

Appendix Table 2 presents summary statistics for firms classified as in pollution-intensive industry and the rest of firms in Panel B.[22] Only 6.5% of all firm-years for which we have matched industry information are classified as pollution-intensive. Despite the lower proportion of high-polluting industry firms, the total emissions of Scope 1 CO_2 emissions by this small fraction of firms is as large as the total emissions by the rest of the sample (93.5%).[23]

With this definition of pollution-intensive industries, we test whether their sensitivity to environmental policy strictness is different from that of firms in other industries. The industry analysis is presented in Table 6. Focusing on Scope 1 emissions (Panel A), the regressions in Columns (1) and (2) show that firms in pollution-intensive industries are not sensitive to environmental policies in regard to their global emissions or home emissions (F-test is not statistically significant). In contrast, Column (3) shows that in regard to emissions in foreign countries, these firms are twice as sensitive to home environmental policies. Hence, when home

[21] See http://ec.europa.eu/eurostat/web/environment/emissions-of-greenhouse-gases-and-air-pollutants/air-emission-accounts/database.
[22] We lost some firm-year observations because we could not map into the NACE industry codes for a subset of sample.
[23] Firms in pollution-intensive industries are responsible for 52% of global Scope 1 CO_2 pollution. We reach this conclusion by summing the tonnage of CO_2 emissions across all firm-years in both parts of the sample.

environmental policies are strict, firms in pollution-intensive industries emit significantly more in foreign countries. Panel B presents the corresponding results for Scope 2 emissions. Overall, the results are similar, albeit not identical. Columns (1) and (2) show that firms in pollution-intensive industries are sensitive to home environmental policies to a lesser degree than firms in non-pollution-intensive industries. Columns (3) and (4) show analogous results to those in the corresponding columns of Panel A: Firms in pollution-intensive industries have nearly double the sensitivity to home environmental policies when it comes to polluting in foreign countries.

These results are especially important because firms in pollution-intensive industries emit materially greater amounts of CO_2. Thus, environmental policies that target these industries may be more effective in reducing total emissions. At the same time, our results show that firms in these industries are polluting significantly more in foreign countries when their home country has more stringent policies. This effect potentially indicates that the cost of reducing emissions in these industries is high, causing firms to transfer polluting activities abroad.

4 Additional Tests and Robustness Checks

4.1 The Influence of Stringency and Enforcement of Environmental Regulation

Our measure of a country's environmental regulation rests on both stringency and enforcement. Thus, we also investigate each of these factors separately, to determine whether our findings are driven by either the stringency or the enforcement of environmental regulation at home, or by both. In Appendix Table 3, we address this issue and separate SEER into its two components: SER (stringency of environmental regulation) and EER (enforcement of environmental regulation). In Panels A and B, we investigate the individual effects of SER and EER on firms' Scope 1 and Scope 2 emissions levels, respectively. Our results show that individually, both the stringency of environmental regulation and the enforcement of this regulation significantly affect emissions levels in the same ways. The results are in line with our main findings reported in Table 3: Firms in countries with more stringent and more strongly enforced environmental regulations emit less in total, less at home but more abroad. The individual effects of SER and EER are economically meaningful: a one-standard deviation increase in SER (0.56) is associated with an up to a 30% decrease in emissions at home and an up to a 37% increase in emissions abroad.[24] Similarly, a one-standard deviation increase in EER (0.68) is associated with an up to a 34% decrease in emissions at home and an up to a 40% increase in emissions abroad.[25]

In Panels C and D of Appendix Table 3, we go one step further and investigate the simultaneous effects of SER and EER on emissions levels. To do so, we orthogonalize EER in our regression specifications. The results of this exercise are as follows. Although the stringency of environmental regulations, SER, negatively affects overall and home emissions levels, it positively affects the absolute and relative foreign emissions levels. These results are consistent with our previously documented findings. Similarly, the enforcement of environmental regulation, EER, significantly affects home and foreign emissions levels above and beyond SER, with the exception of foreign Scope 2 emissions, which just miss the 10% significance level (Column (3) in Panel D). This finding implies that the enforcement and stringency of environmental regulations are complementary in shaping a firm's pollution behavior.

4.2 Addressing Potential Self-Reporting Bias

The underlying information from CDP on emissions is self-reported by firms. This fact raises concerns that our data could have a self-reporting bias. To address this concern, we conduct a subsample analysis similar to our main analysis in Table 3. This time, however, we only include in our sample firms whose CO_2 emissions are externally verified by the firms' auditors. In doing so, we are able to rule out the potential effects of a self-reporting bias on our findings. The drawback of this subsample is that it reduces the sample size by about 40%.

The findings of this subsample analysis are presented in Appendix Table 4. The results are generally consistent with our main results in Table 3: SEER has a negative effect on global and home emission levels and a positive relation with foreign emissions (both absolute and relative). This observation implies that for firms whose reported emissions are externally verified, stricter

[24] From Column (3) in Panel A: 100 * ($e^{-0.47 * 0.56}$ – 1) = –23.1%; from Column (3) in Panel B: 100 * ($e^{-0.65 * 0.56}$ – 1) = –30.5%; from Column (5) in Panel A: 100 * ($e^{0.46 * 0.56}$ – 1) = 29.4%; from Column (5) in Panel B: 100 * ($e^{0.57 * 0.56}$ – 1) = 37.6%.

[25] From Column (4) in Panel A: 100 * ($e^{-0.45 * 0.68}$ – 1) = –26.4%; from Column (4) in Panel B: 100 * ($e^{-0.62 * 0.68}$ – 1) = –34.4%; from Column (6) in Panel A: 100 * ($e^{0.44 * 0.68}$ – 1) = 34.9%; from Column (6) in Panel B: 100 * ($e^{0.50 * 0.68}$ – 1) = 40.5%.

environmental regulations in the home market lead to lower emissions at home but to higher emissions abroad. The economic effects are similar to those reported in Table 3. For firms with externally verified emissions, a one-standard deviation (0.90) increase in the strictness of environmental policies is associated with an up to a 31% smaller share of home emissions[26] and with an up to a 33% greater share of foreign emissions.[27]

5 Conclusion

Pollution and the emission of greenhouse gases is an undesired externality of manufacturing activity that is costly to avoid. As a result, firms are likely to find ways to circumvent costly CO_2 pollution abatement requirements. One strategy could be to transfer manufacturing activities that produce CO_2 to countries where environmental regulations are less stringently defined and enforced than in the firm's home market, a concept which is known as carbon leakage. As such, the argument goes that countries are also competing in an international marketplace for industrial activity. Therefore, countries may present their weak environmental policies as an advantage to attract industrial activities, and thus boost economic growth and employment. The main results in this paper imply that the combination of these demand and supply factors results in the strategic polluting behaviors of firms: Firms perform their production activities in countries with looser environmental regulation relative to their home country.

Our paper sheds light on this argument using a novel dataset comprising firm-level CO_2 emissions data. We find a strong pattern that companies indeed locate their CO_2 emitting activities in countries where environmental regulation is less developed and less stringently enforced: Scope 1 and Scope 2 CO_2 emission levels are significantly higher abroad if environmental regulation in the home market is more stringent than abroad. These results hold in a standard firm-level framework as well as in a disaggregated firm-country-level context.

Our study has important implications for firms and countries. The main results on global CO_2 emission analyses suggest that national regulations can be beneficial: Firms that are highly

[26] From Column (2) in Panel A: 100 * ($e^{-0.37 * 0.9}$ – 1) = –28.3%; from Column (2) in Panel B: 100 * ($e^{-0.41 * 0.9}$ – 1) = –30.9%.
[27] From Column (3) in Panel A: 100 * ($e^{0.32 * 0.9}$ – 1) = 33.4%; from Column (3) in Panel B: 100 * ($e^{0.28 * 0.9}$ – 1) = 28.7%.

regulated in their home country pollute less globally. However, we also document that regulatory arbitrage takes place: Firms locate their CO_2-intensive activities abroad to countries where environmental regulation is less strict than in the home market. These findings imply that to effectively combat pollution and climate change, national regulation is of only limited effect. Concerted action among countries is preferable so that the overall CO_2 balance will not increase. The 2015 Paris Agreement on climate change was an important step toward achieving this goal. If no coordinated effort is undertaken to address climate change, major stakeholders, such as large firms, will find ways to at least partially circumvent strict environmental regulations in certain parts of the world and move their production activities elsewhere.

For multinational firms with production facilities all around the globe, our results imply that—depending on how quickly and effectively countries implement the Paris Agreement—they may continue to benefit from the regulatory arbitrage opportunities we document or they should be prepared to invest in pollution-abatement methods and techniques. Whether the Paris Agreement will harmonize national environmental regulation to such an extent that firms will no longer have an option to locate operations purely based on concerns about the strictness of environmental regulation in a particular country remains to be seen.

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Table 1. Summary Statistics

The table shows descriptive statistics for all firms that report at least 85% of their global emissions on a country level and that have their headquarters in countries with environmental regulation data. Overall, 1,813 firms from 48 different home countries report Scope 1 emissions, and 1,863 firms from 47 different home countries report Scope 2 emissions. Our proxy for environmental regulation (SEER) combines the World Economic Forum's assessment of a country's stringency and enforcement of environmental regulation. The proxy ranges from 0 to 7, with higher values indicating stricter environmental regulation.

Panel A: Scope 1 Emissions

		Average across firms			
Year	Number of firms	Firm's global emissions in metric tons	Firm's emissions in home country in % of firm's total global emissions	Number of countries in which firm has emissions	Environmental regulation (SEER) in firm's home country
2008	573	5,004,705	71.9	6.0	3.9
2009	792	3,110,120	73.2	6.0	4.0
2010	734	3,119,675	61.4	8.1	4.1
2011	807	3,059,106	61.5	8.2	4.1
2012	855	3,145,869	58.8	8.6	4.2
2013	883	2,990,603	59.1	9.1	4.1
2014	1,030	2,724,609	56.8	9.0	4.2
2015	1,054	2,623,531	56.5	9.0	4.1

Panel B: Scope 2 Emissions

		Average across firms			
Year	Number of firms	Firm's global emissions in metric tons	Firm's emissions in home country in % of firm's total global emissions	Number of countries in which firm has emissions	Environmental regulation (SEER) in firm's home country
2008	543	925,672	69.4	6.8	4.0
2009	812	740,259	69.9	6.9	4.0
2010	756	687,451	58.3	9.5	4.1
2011	834	654,047	57.1	9.9	4.1
2012	901	685,918	53.7	10.2	4.2
2013	918	728,495	53.3	10.7	4.1
2014	1,083	526,509	52.4	10.6	4.1
2015	1,100	521,705	52.6	10.6	4.1

Table 1. Summary Statistics (Cont.)

Panel C: Stringency and Enforcement of Environmental Regulation (SEER)

						Average across firms in (as of 2008)		
N = 150	Mean	Std Dev	Min	Median	Max	Top 50	Mid 50	Bottom 50
2008	2.300	1.270	0.054	1.940	5.588	3.802	1.955	1.135
2009	2.348	1.323	0.124	1.902	5.761	3.921	1.939	1.175
2010	2.327	1.321	0.223	1.845	6.041	3.860	1.877	1.234
2011	2.344	1.320	0.270	1.940	5.936	3.860	1.915	1.258
2012	2.358	1.296	0.296	1.971	5.853	3.833	1.957	1.276
2013	2.416	1.255	0.520	2.030	5.589	3.827	2.026	1.386
2014	2.465	1.243	0.372	2.150	5.651	3.854	2.036	1.496
2015	2.439	1.225	0.104	2.131	5.560	3.790	2.014	1.506

Table 2. Descriptive Statistics

The table presents descriptive statistics for our CO_2 variables, the stringency and enforcement of the environmental regulation (SEER) variable as well as specific firm-level variables that are used in the empirical analyses that follow.

Panel A: Sample of Firm-Level Observations

	N	Mean	Std Dev	Min	Median	Max
Scope 1 CO_2 emissions						
Global emissions ('000 tons)	6,325	3,149.84	13,693.48	0.00	88.81	183,400.00
Home emissions ('000 tons)	6,325	1,846.21	8,813.60	0.00	33.89	180,000.00
Foreign emissions ('000 tons)	6,325	1,303.63	8,487.66	0.00	13.28	175,571.07
Foreign emissions (% of global emissions)	6,325	38.30	34.68	0.00	30.23	100.00
Scope 2 CO_2 emissions						
Global emissions ('000 tons)	6,530	678.94	2,683.42	0.00	136.04	120,000.00
Home emissions ('000 tons)	6,530	374.62	2,069.16	0.00	49.23	120,000.00
Foreign emissions ('000 tons)	6,530	304.31	1,541.90	0.00	27.43	75,300.00
Foreign emissions (% of global emissions)	6,530	42.83	35.78	0.00	37.52	100.00
Environmental regulation in firm's home country						
SEER (0-7)	7,016	4.11	0.90	1.07	4.00	6.04
SER (0-7)	7,016	5.43	0.56	2.90	5.38	6.63
EER (0-7)	7,016	5.23	0.68	2.58	5.23	6.41
Firm characteristics						
Assets ($m)	7,016	60.70	194.00	0.31	8.83	1,485.05
Foreign asset share (%)	5,417	26.40	26.15	0.00	17.54	98.77
Corporate governance (0-100)	6,086	65.07	28.11	1.55	76.53	97.67
Home country characteristics						
GDP ($bn)	7,016	5,384.21	6,106.45	19.56	2,646.00	18,040.00
GDP per capita growth (%)	7,016	0.64	2.43	-9.00	0.93	25.56

Table 2. Descriptive Statistics (Cont.)

Panel B: Sample of Firm-Country-Level Observations

	N	Mean	Std Dev	Min	Median	Max
Scope 1 CO_2 emissions						
Foreign emissions ('000 tons)	671,717	8.75	319.98	0.00	0.00	66,000.00
Foreign emissions (% of global emissions)	671,717	0.27	2.90	0.00	0.00	100.00
Scope 2 CO_2 emissions						
Foreign emissions ('000 tons)	689,448	2.23	70.23	0.00	0.00	14,000.00
Foreign emissions (% of global emissions)	689,448	0.31	3.15	0.00	0.00	100.00
Environmental regulation						
$SEER_{home} - SEER_{foreign}$	744,782	1.80	1.52	-4.26	2.04	5.67
Firm characteristics						
Assets ($m)	744,782	51.05	146.77	0.12	8.79	960.47
Foreign asset share (%)	744,782	26.46	26.14	0.00	17.81	98.77
Foreign country characteristics						
GDP ($bn)	744,782	462.94	1,519.03	0.69	52.91	18,039.99
Country pair characteristics						
Geographic distance (km)	744,782	8,196.11	4,090.00	141.00	8,403.00	19,885.00
Common border (0/1)	744,782	0.01	0.12	0.00	0.00	1.00
Common colonial history (0/1)	744,782	0.05	0.22	0.00	0.00	1.00
Trade ($bn)	744,782	11.40	47.28	0.00	0.66	660.22

Table 3. Analysis of Firm-Level Emissions: Effect of Domestic Environmental Policies

The table presents evidence about the relation between emissions in foreign countries and home-country environmental policies. Panels A and B show results for Scope 1 and 2 emissions, respectively. Columns (1) and (2) are estimated with ordinary least squares, and Columns (3) to (8) are estimated using a Tobit model. Standard errors are clustered by firm. SEER is our proxy for stringency and enforcement of environmental regulation in the firm's home country, with higher values indicating stricter regulation. For each independent variable, the top row shows the estimated coefficient and the bottom row shows the *t*-statistic. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: Scope 1 Emissions

Dependent variable:	ln(1+Global emissions (tons))		ln(1+Home emissions (tons))		ln(1+Foreign emissions (tons))		Foreign emissions in % of global emissions	
Specification:	OLS	OLS	Tobit	Tobit	Tobit	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SEER	-0.18 ***	-0.15 ***	-0.38 ***	-0.30 ***	0.40 ***	0.28 **	4.54 ***	3.31 ***
	(-3.56)	(-2.66)	(-4.21)	(-2.82)	(3.84)	(2.47)	(4.06)	(2.81)
Firm characteristics								
ln(Assets)	1.03 ***	1.05 ***	1.00 ***	1.07 ***	1.43 ***	1.30 ***	3.83 ***	1.82 **
	(28.03)	(27.01)	(15.79)	(15.87)	(19.33)	(18.16)	(4.94)	(2.51)
Foreign asset share		0.00		-0.03 ***		0.04 ***		0.62 ***
		(0.34)		(-7.30)		(11.87)		(16.71)
Home country characteristics								
ln(GDP)	0.03	0.01	0.44 ***	0.32 ***	-0.43 ***	-0.19 **	-8.38 ***	-5.16 ***
	(0.76)	(0.30)	(6.24)	(3.97)	(-5.86)	(-2.50)	(-10.90)	(-6.36)
GDP per capita growth	0.01	0.00	0.05	0.03	-0.20 ***	-0.15 ***	-1.77 ***	-1.23 ***
	(0.77)	(0.28)	(1.60)	(0.80)	(-4.86)	(-3.73)	(-4.33)	(-3.20)
Fixed effects								
Year	yes	yes	yes	yes	yes	yes	yes	yes
Industry	yes	yes	yes	yes	yes	yes	yes	yes
Adjusted/Pseudo R-squared	0.703	0.692	0.108	0.112	0.091	0.104	0.030	0.052
Observations	6,325	4,919	6,325	4,919	6,325	4,919	6,325	4,919
of which censored at 0			274	226	719	481	719	481
of which censored at 100							274	226

Table 3. Analysis of Firm-Level Emissions (Cont.)

Panel B: Scope 2 Emissions

Dependent variable:	ln(1+Global emissions (tons))		ln(1+Home emissions (tons))		ln(1+Foreign emissions (tons))		Foreign emissions in % of global emissions	
Specification:	OLS	OLS	Tobit	Tobit	Tobit	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SEER	-0.20 ***	-0.18 ***	-0.48 ***	-0.42 ***	0.41 ***	0.34 ***	7.38 ***	6.67 ***
	(-5.07)	(-4.19)	(-5.72)	(-4.29)	(4.25)	(3.47)	(6.90)	(5.97)
Firm characteristics								
ln(Assets)	0.92 ***	0.93 ***	0.80 ***	0.87 ***	1.31 ***	1.21 ***	4.36 ***	2.53 ***
	(29.81)	(27.96)	(14.33)	(14.47)	(19.79)	(19.16)	(5.96)	(3.73)
Foreign asset share		-0.00		-0.03 ***		0.04 ***		0.61 ***
		(-1.41)		(-8.16)		(11.20)		(17.79)
Home country characteristics								
ln(GDP)	0.08 ***	0.06 **	0.52 ***	0.40 ***	-0.29 ***	-0.11 *	-8.50 ***	-5.40 ***
	(2.76)	(2.05)	(7.88)	(5.50)	(-4.50)	(-1.71)	(-11.25)	(-6.90)
GDP per capita growth	0.02	0.01	0.05	0.02	-0.21 ***	-0.14 ***	-1.87 ***	-1.13 ***
	(1.32)	(0.65)	(1.64)	(0.74)	(-5.11)	(-3.64)	(-4.44)	(-3.04)
Fixed effects								
Year	yes	yes	yes	yes	yes	yes	yes	yes
Industry	yes	yes	yes	yes	yes	yes	yes	yes
Adjusted/Pseudo R-squared	0.588	0.594	0.073	0.083	0.082	0.099	0.033	0.054
Observations	6,530	5,018	6,530	5,018	6,530	5,018	6,530	5,018
of which censored at 0			230	196	693	430	693	430
of which censored at 100							231	196

Table 4. Analysis of Firm-Country-Level Emissions: Effect of Environmental Policy Gaps

The table shows the effect of environmental regulation gaps between two countries on the firms' emissions in a specific country, estimated as Tobit regressions with standard errors clustered by country-pair. $SEER_{home} - SEER_{foreign}$ is our proxy for stringency and enforcement of environmental regulation in the home minus the foreign country, with higher values indicating stricter regulation at home. For each independent variable, the top row shows the estimated coefficient and the bottom row shows the *t*-statistic. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	Scope 1 emissions		Scope 2 emissions	
Dependent variable:	ln(1+Foreign emissions (tons))	Foreign emissions in % of global emissions	ln(1+Foreign emissions (tons))	Foreign emissions in % of global emissions
Specification:	Tobit	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)
$SEER_{home}$ - $SEER_{foreign}$	0.40 ***	0.52 ***	0.38 ***	0.39 **
	(2.93)	(2.93)	(3.00)	(2.44)
Controls - firm characteristics				
ln(Assets)	2.38 ***	2.29 ***	1.96 ***	1.88 ***
	(32.79)	(16.92)	(31.20)	(14.27)
Foreign asset share	0.05 ***	0.07 ***	0.04 ***	0.05 ***
	(16.82)	(11.79)	(14.02)	(9.58)
Controls - foreign country characteristics				
ln(GDP)	-0.51	-0.67	0.49	0.61
	(-1.38)	(-1.39)	(1.44)	(1.30)
Gravity controls - country pair characteristics				
ln(Geographic distance)	-1.67 ***	-2.16 ***	-1.33 ***	-1.83 ***
	(-5.49)	(-4.99)	(-4.99)	(-4.41)
Common border	0.80	2.18 *	0.67	1.75
	(1.14)	(1.86)	(1.06)	(1.44)
Common colonial history	3.04 ***	4.42 ***	2.97 ***	4.46 ***
	(6.38)	(6.38)	(7.42)	(6.60)
ln(Trade)	1.93 ***	2.52 ***	1.86 ***	2.44 ***
	(10.02)	(8.53)	(10.72)	(8.93)
Fixed effects				
Year	yes	yes	yes	yes
Industry	yes	yes	yes	yes
Foreign country	yes	yes	yes	yes
Home country	yes	yes	yes	yes
Pseudo R-squared	0.198	0.178	0.203	0.183
Observations	671,717	671,717	689,448	689,448
of which censored at 0	636,406	636,406	645,856	645,856
of which uncensored	35,311	35,296	43,592	43,573
of which censored at 100		15		19

Table 5. Environmental Regulation and Firms' Corporate Governance

The table shows results estimated using ordinary least squares (Column 1) and Tobit (Columns 2-4) regressions with standard errors clustered by firm. For each independent variable, the top row shows the estimated coefficient and the bottom row shows the *t*-statistic. The *F*-test assesses the joint significance of the coefficients of SEER and its interaction effect. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: Scope 1 Emissions

Dependent variable:	ln(1+Global emissions (tons))		ln(1+Home emissions (tons))		ln(1+Foreign emissions (tons))		Foreign emissions in % of global emissions	
Specification:	OLS		Tobit		Tobit		Tobit	
	(1)		(2)		(3)		(4)	
SEER	-0.14	**	-0.22	*	0.41	***	3.45	**
	(-2.11)		(-1.94)		(2.76)		(2.47)	
SEER*I(Strong governance)	0.00		-0.69	**	-0.36	*	4.67	*
	(0.01)		(-2.46)		(-1.68)		(1.90)	
Firm characteristics								
ln(Assets)	1.03	***	1.07	***	1.23	***	1.56	**
	(23.20)		(14.33)		(15.28)		(2.02)	
Foreign asset share	0.00		-0.03	***	0.04	***	0.61	***
	(0.71)		(-6.82)		(10.77)		(15.46)	
Strong governance$_D$	0.09		2.54	**	2.26	**	-10.07	
	(0.18)		(2.23)		(2.45)		(-0.99)	
Home country characteristics								
ln(GDP)	0.01		0.37	***	-0.29	***	-6.19	***
	(0.32)		(4.05)		(-3.61)		(-7.29)	
GDP per capita growth	0.00		0.02		-0.12	***	-0.91	**
	(0.10)		(0.54)		(-3.22)		(-2.39)	
Fixed effects								
Year	yes		yes		yes		yes	
Industry	yes		yes		yes		yes	
Adjusted/Pseudo R-squared	0.692		0.113		0.106		0.055	
F-test	1.54		10.17	***	0.08		12.04	***
Observations	4,376		4,376		4,376		4,376	
of which censored at 0			196		406		406	
of which censored at 100							196	

Table 5. Environmental Regulation and Firms' Corporate Governance (Cont.)
Panel B: Scope 2 Emissions

Dependent variable:	ln(1+Global emissions (tons))		ln(1+Home emissions (tons))		ln(1+Foreign emissions (tons))		Foreign emissions in % of global emissions	
Specification:	OLS		Tobit		Tobit		Tobit	
	(1)		(2)		(3)		(4)	
SEER	-0.16	***	-0.37	***	0.39	***	6.53	***
	(-3.05)		(-3.69)		(3.03)		(4.95)	
SEER*I(Strong governance)	-0.03		-0.53	*	-0.22		4.33	*
	(-0.34)		(-1.73)		(-1.21)		(1.71)	
Firm characteristics								
ln(Assets)	0.91	***	0.81	***	1.16	***	2.75	***
	(24.33)		(12.44)		(15.88)		(3.72)	
Foreign asset share	-0.00	**	-0.03	***	0.04	***	0.60	***
	(-1.99)		(-7.58)		(9.75)		(15.96)	
Strong governance$_D$	0.14		1.82		1.44	*	-11.99	
	(0.36)		(1.45)		(1.75)		(-1.11)	
Home country characteristics								
ln(GDP)	0.05		0.45	***	-0.19	**	-6.14	***
	(1.39)		(5.16)		(-2.56)		(-7.26)	
GDP per capita growth	0.01		0.03		-0.11	***	-1.00	***
	(0.87)		(0.73)		(-3.06)		(-2.63)	
Fixed effects								
Year	yes		yes		yes		yes	
Industry	yes		yes		yes		yes	
Adjusted/Pseudo R-squared	0.582		0.083		0.098		0.056	
F-test	5.21	**	9.07	***	1.27		21.61	***
Observations	4,442		4,442		4,442		4,442	
of which censored at 0			159		353		353	
of which censored at 100							159	

Table 6. Environmental Regulation and Pollution-Intensive Industries

The table shows results estimated as ordinary least squares (Column 1) and Tobit (Columns 2-4) regressions with standard errors clustered by firm. For each independent variable, the top row shows the estimated coefficient and the bottom row shows the *t*-statistic. The *F*-test assesses the joint significance of the coefficients of SEER and its interaction effect. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: Scope 1 Emissions

Dependent variable:	ln(1+Global emissions (tons))		ln(1+Home emissions (tons))		ln(1+Foreign emissions (tons))		Foreign emissions in % of global emissions	
Specification:	OLS		Tobit		Tobit		Tobit	
	(1)		(2)		(3)		(4)	
SEER	-0.20	***	-0.37	***	0.24	**	3.76	***
	(-3.38)		(-3.26)		(2.05)		(2.93)	
SEER*I(Pollution intensive)	0.30	***	0.28	**	0.24	**	-0.11	
	(5.01)		(2.53)		(1.98)		(-0.09)	
Firm characteristics								
ln(Assets)	1.02	***	1.02	***	1.26	***	1.99	**
	(26.13)		(14.06)		(17.27)		(2.57)	
Foreign asset share	0.00		-0.03	***	0.04	***	0.61	***
	(0.16)		(-7.37)		(10.89)		(15.86)	
Home country characteristics								
ln(GDP)	0.03		0.36	***	-0.14	*	-5.15	***
	(0.64)		(4.27)		(-1.80)		(-5.99)	
GDP per capita growth	0.01		0.03		-0.13	***	-1.05	***
	(0.90)		(0.85)		(-3.20)		(-2.69)	
Fixed effects								
Year	yes		yes		yes		yes	
Industry	yes		yes		yes		yes	
Adjusted/Pseudo R-squared	0.676		0.102		0.108		0.050	
F-test	1.59		0.32		8.54	***	4.27	**
Observations	4,559		4,559		4,559		4,559	
of which censored at 0			216		431		431	
of which censored at 100							216	

Table 6. Environmental Regulation and Pollution-Intensive Industries (Cont.)

Panel B: Scope 2 Emissions

Dependent variable:	ln(1+Global emissions (tons))		ln(1+Home emissions (tons))		ln(1+Foreign emissions (tons))		Foreign emissions in % of global emissions	
Specification:	OLS		Tobit		Tobit		Tobit	
	(1)		(2)		(3)		(4)	
SEER	-0.23	***	-0.51	***	0.30	***	7.03	***
	(-5.01)		(-4.95)		(2.99)		(5.91)	
SEER*I(Pollution intensive)	0.12	**	0.11		0.21	**	0.39	
	(2.54)		(1.26)		(2.14)		(0.38)	
Firm characteristics								
ln(Assets)	0.93	***	0.84	***	1.21	***	2.98	***
	(27.67)		(13.28)		(18.95)		(4.23)	
Foreign asset share	-0.00	*	-0.03	***	0.03	***	0.59	***
	(-1.77)		(-8.01)		(10.30)		(16.93)	
Home country characteristics								
ln(GDP)	0.08	**	0.43	***	-0.06		-5.40	***
	(2.52)		(5.83)		(-0.95)		(-6.66)	
GDP per capita growth	0.02		0.04		-0.11	***	-1.09	***
	(1.33)		(1.13)		(-3.08)		(-2.87)	
Fixed effects								
Year	yes		yes		yes		yes	
Industry	yes		yes		yes		yes	
Adjusted/Pseudo R-squared	0.601		0.085		0.098		0.052	
F-test	2.82	*	8.96	***	14.01	***	23.04	***
Observations	4,724		4,724		4,724		4,724	
of which censored at 0			184		380		380	
of which censored at 100							184	

Appendix Table 1. Variable Definitions and Sources

Panel A: Variables Used in Firm-Level Analyses

Variable	Description	Units	Original Data Source
Dependent variables			
Global emissions	Firm i's CO_2 emissions globally in year t, calculated for either Scope 1 or Scope 2 emissions	tons	CDP
Home emissions	Firm i's CO_2 emissions in home country in year t, calculated for either Scope 1 or Scope 2 emissions	tons	CDP
Foreign emissions	Firm i's CO_2 emissions in all foreign countries combined in year t, calculated for either Scope 1 or Scope 2 emissions	tons	CDP
Foreign emissions in % of global emissions	Firm i's CO_2 emissions in all foreign countries combined in year t in percent of firm i's global CO_2 emissions in year t, calculated for either Scope 1 or Scope 2 emissions	0-100 with 1.0=1%	CDP
Independent variables			
SER	Stringency of environmental regulation in firm i's home country in year t	0-7	World Economic Forum
EER	Enforcement of environmental regulation in firm i's home country in year t	0-7	World Economic Forum
SEER	Stringency and enforcement of environmental regulation in firm i's home country in year t; calculated as SEER = (SER*EER)/7	0-7	World Economic Forum
Assets	Total assets of firm i in year t (WC02999)	US$ million	Worldscope
Foreign asset share	Firm i's foreign assets in % of total assets in year t (WC08736)	0-100 with 1.0=1%	Worldscope
Strong governance$_D$	Dummy equal to 1 if firm i's corporate governance score (CGVSCORE) in year t is larger than the sample median, 0 otherwise	0/1	Asset4
Pollution intensive$_D$	Dummy equal to 1 if a firm belongs to pollution-intensive industry, 0 otherwise; industries with NACE Industries Codes (Revision 2) C19, C23, C24, D, H50 and H51 are considered to be pollution intensive; the NACE code is mapped to the firm's NAICS code using the Index Correspondent Tables provided by Eurostat, RAMON (Reference And Management of Nomenclatures)	0/1	Compustat, Eurostat
External verification$_D$	Dummy equal to 1 if firm i's emissions in year t are externally verified, 0 otherwise	0/1	CDP
GDP	Gross domestic product in firm i's home country in year t	current US$ million	World Bank's World Development Indicators
GDP per capita growth	Annual percentage growth rate of GDP per capita for firm i's home country in year t	0-100 with 1.0=1%	World Bank's World Development Indicators

Appendix Table 1. Variable Definitions and Sources (Cont.)

Panel B: Variables Used in Firm-Country-Level Analyses

Variable	Description	Units	Original Data Source
Dependent variables			
Foreign emissions	Firm i's CO2 emissions in foreign country c in year t, calculated for either Scope 1 or Scope 2 emissions	tons	CDP
Foreign emissions in % of global emissions	Firm i's CO2 emissions in foreign country c in year t in percent of firm i's global CO2 emissions in year t, calculated for either Scope 1 or Scope 2 emissions	0-100 with 1.0=1%	CDP
Independent variables			
$SEER_{home}$ - $SEER_{foreign}$	Difference between stringency and enforcement of environmental regulation in firm i's home country and foreign country c in year t; each country's SEER is calculated as SEER = (SER*EER)/7	-7 to +7	World Economic Forum
Assets	Total assets of firm i in year t (WC02999)	US$ million	Worldscope
Foreign asset share	Firm i's foreign assets in % of total assets in year t (WC08736)	0-100 with 1.0=1%	Worldscope
GDP	Gross domestic product in foreign country c in year t	current US$ million	World Bank's World Development Indicators
Geographic distance	Geographic distance between firm i's home country and foreign country c, measured using the great circle distance formula	km	www.distancefromto.net
Common border	Dummy equal to 1 if firm I's home country and the foreign country c share a land border, 0 otherwise	0/1	Glick and Rose (2016), CIA World Factbook
Common colonial history	Dummy equal to 1 if firm i's home country and foreign country c have a colonial history or belonged to same country	0/1	Glick and Rose (2016)
Trade	Sum of exports and imports between firm i's home country and foreign country c in year t	US$	IMF's Direction of Trade Statistics

Panel C: Fixed effects used in firm-level and firm-country-level analyses

Variable	Description	Units	Original Data Source
Year	Dummies identifying the year t in which firm i emits CO_2, 2008-2015	0/1	CDP
Industry	Dummies based on 2-digit SIC codes (WC07021)	0/1	Worldscope
Foreign country	Dummies identifying the foreign country c in which firm i	0/1	CDP
Home country	Dummies identifying the home country in which firm i is headquartered	0/1	CDP

Appendix Table 2. Pollution-Intensive Industries

The table presents summary statistics about the pollution intensity of industries and firms in pollution-intensive versus non-pollution-intensive industries. Panel A shows the CO_2 intensity of various industries in the European Union (2018 member states). CO_2 intensity is measured as the kilograms of CO_2 per Euro of gross value added. For comparability over time, gross value added is measured in real terms (chain linked volumes at 2010 prices) to eliminate the effects of inflation. Pollution-intensive industries are marked with an asterisk and bold face. Source: Eurostat, Air emission accounts, Air emissions intensities by NACE Rev. 2 activity (env_ac_aeint_r2): http://ec.europa.eu/eurostat/web/environment/emissions-of-greenhouse-gases-and-air-pollutants/air-emission-accounts/database. Panel B presents summary statistics for all firms that could be mapped into the NACE industries. Panel C presents summary statistics for the firms classified as having material polluting activities. Panel D presents summary statistics for the firms classified as not having material polluting activities.

Panel A: Industry CO_2 Emission Intensity (kg per Euro), by Year

NACE Industry Code (Revision 2)	2008	2009	2010	2011	2012	2013	2014	2015
TOTAL - Total - all NACE activities	0.30	0.28	0.28	0.27	0.27	0.26	0.24	0.24
A - Agriculture, forestry and fishing	0.55	0.54	0.57	0.55	0.58	0.56	0.53	0.52
A01 - Crop and animal production, hunting and related service activities	0.56	0.55	0.59	0.57	0.60	0.58	0.55	0.54
A02 - Forestry and logging	0.22	0.21	0.22	0.20	0.19	0.19	0.17	0.18
A03 - Fishing and aquaculture	1.27	1.23	1.19	1.24	1.23	1.21	1.11	1.11
B - Mining and quarrying	0.54	0.54	0.53	0.55	0.51	0.52	0.53	0.53
C - Manufacturing	0.54	0.53	0.51	0.48	0.47	0.45	0.44	0.42
C10-C12 - Manufacture of food products; beverages and tobacco products	0.28	0.26	0.26	0.24	0.25	0.24	0.23	0.21
C13-C15 - Manufacture of textiles, wearing apparel, leather and related products	0.16	0.16	0.15	0.14	0.14	0.14	0.13	0.14
C16 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.22	0.20	0.19	0.17	0.17	0.17	0.16	0.15
C17 - Manufacture of paper and paper products	0.86	0.83	0.83	0.80	0.74	0.74	0.69	0.70
C18 - Printing and reproduction of recorded media	0.09	0.08	0.09	0.08	0.08	0.09	0.08	0.09
C19 - Manufacture of coke and refined petroleum products*	**5.91**	**5.26**	**5.80**	**5.84**	**7.34**	**5.93**	**5.36**	**3.59**
C20 - Manufacture of chemicals and chemical products	1.32	1.30	1.26	1.23	1.23	1.20	1.12	1.04
C21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05
C22 - Manufacture of rubber and plastic products	0.17	0.15	0.16	0.13	0.13	0.15	0.14	0.14
C23 - Manufacture of other non-metallic mineral products*	**3.36**	**3.31**	**3.27**	**3.09**	**3.03**	**2.97**	**2.92**	**2.92**
C24 - Manufacture of basic metals*	**3.23**	**2.90**	**3.08**	**2.86**	**2.55**	**2.43**	**2.31**	**2.21**
C25 - Manufacture of fabricated metal products, except machinery and equipment	0.09	0.11	0.10	0.09	0.09	0.09	0.08	0.09
C26 - Manufacture of computer, electronic and optical products	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03
C27 - Manufacture of electrical equipment	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05
C28 - Manufacture of machinery and equipment n.e.c.	0.05	0.06	0.05	0.05	0.04	0.05	0.04	0.04
C29 - Manufacture of motor vehicles, trailers and semi-trailers	0.07	0.08	0.07	0.06	0.06	0.06	0.05	0.05
C30 - Manufacture of other transport equipment	0.06	0.06	0.06	0.05	0.04	0.04	0.04	0.04
C31+C32 - Manufacture of furniture; other manufacturing	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06
C33 - Repair and installation of machinery and equipment	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
D - Electricity, gas, steam and air conditioning supply*	**6.29**	**5.69**	**5.70**	**5.91**	**5.63**	**5.56**	**5.26**	**5.24**
E - Water supply; sewerage, waste management and remediation activities	0.37	0.36	0.37	0.35	0.34	0.35	0.35	0.34
E36 - Water collection, treatment and supply	0.22	0.21	0.19	0.17	0.17	0.18	0.18	0.18
E37-E39 - Sewerage, waste management, remediation activities	0.43	0.42	0.43	0.41	0.41	0.41	0.41	0.40
F - Construction	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09
G - Wholesale and retail trade; repair of motor vehicles and motorcycles	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05
G45 - Wholesale and retail trade and repair of motor vehicles and motorcycles	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06
G46 - Wholesale trade, except of motor vehicles and motorcycles	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05
G47 - Retail trade, except of motor vehicles and motorcycles	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05
H - Transportation and storage	0.90	0.88	0.87	0.85	0.83	0.82	0.81	0.83
H49 - Land transport and transport via pipelines	0.79	0.78	0.78	0.75	0.72	0.73	0.72	0.72
H50 - Water transport*	**3.37**	**3.39**	**3.40**	**3.43**	**3.26**	**3.01**	**3.25**	**3.66**
H51 - Air transport*	**4.10**	**4.47**	**3.93**	**3.88**	**3.74**	**3.70**	**4.10**	**4.35**
H52 - Warehousing and support activities for transportation	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
H53 - Postal and courier activities	0.11	0.11	0.12	0.11	0.11	0.12	0.12	0.13

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Appendix Table 2. Pollution-Intensive Industries (Cont.)

(continues from previous page)

NACE Industry Code (Revision 2)	2008	2009	2010	2011	2012	2013	2014	2015
I - Accommodation and food service activities	0.06	0.06	0.07	0.06	0.06	0.06	0.05	0.05
J - Information and communication	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
J58 - Publishing activities	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
J59+J60 - Motion picture, video, television programme production; programming and b	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
J61 - Telecommunications	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
J62+J63 - Computer programming, consultancy, and information service activities	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
K - Financial and insurance activities	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
K64 - Financial service activities, except insurance and pension funding	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
K65 - Insurance, reinsurance and pension funding, except compulsory social security	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
K66 - Activities auxiliary to financial services and insurance activities	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
L - Real estate activities	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
M - Professional, scientific and technical activities								
M69+M70 - Legal and accounting activities; activities of head offices; management consultancy activities	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
M71 - Architectural and engineering activities; technical testing and analysis	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
M72 - Scientific research and development	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
M73 - Advertising and market research	0.03	0.04	0.03	0.03	0.03	0.03	0.02	0.02
M74+M75 - Other professional, scientific and technical activities; veterinary activities	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03
N - Administrative and support service activities	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
N77 - Rental and leasing activities	0.10	0.10	0.09	0.09	0.09	0.09	0.08	0.08
N78 - Employment activities	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N79 - Travel agency, tour operator reservation service and related activities	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03
N80-N82 - Security and investigation, service and landscape, office administrative and support activities	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03
O - Public administration and defence; compulsory social security	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
P - Education	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03
Q - Human health and social work activities								
Q86 - Human health activities	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Q87+Q88 - Residential care activities and social work activities without accommodation	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04
R - Arts, entertainment and recreation	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
R90-R92 - Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03
R93 - Sports activities and amusement and recreation activities	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06
S - Other service activities	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.05
S94 - Activities of membership organisations	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.04
S95 - Repair of computers and personal and household goods	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.06
S96 - Other personal service activities	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04

Appendix Table 2. Pollution-Intensive Industries (Cont.)

Panel B: Summary Statistics: Pollution-Intensive vs. Non-Pollution-Intensive Industries Industries

	Pollution-Intensive Industry				**Non-Pollution-Intensive Industry**			
	N	Mean	Std Dev	Median	N	Mean	Std Dev	Median
Scope 1 CO_2 emissions								
Global emissions ('000 tons)	296	13,941	28,585	3,100	4,263	883	3,501	64
Home emissions ('000 tons)	296	5,763	11,096	1,425	4,263	478	1,882	24
Foreign emissions ('000 tons)	296	8,178	26,955	760	4,263	406	2,468	12
Foreign emissions (% of global emissions)	296	40.56	33.99	35.69	4,263	40.08	34.72	32.48
Scope 2 CO_2 emissions								
Global emissions ('000 tons)	319	1,949	3,232	625	4,405	594	2,731	127
Home emissions ('000 tons)	319	678	1,296	231	4,405	351	2,389	43
Foreign emissions ('000 tons)	319	1,271	2,957	157	4,405	244	1,121	31
Foreign emissions (% of global emissions)	319	44.95	35.14	43.33	4,405	44.96	35.18	41.60

Appendix Table 3. SER vs. EER

The table presents evidence about the relation between emissions in foreign countries and home-country stringency and enforcement (SER and EER) of environmental policies. Panels A and C show Scope 1 emissions, and Panels B and D show Scope 2 emissions. Columns (1) and (2) are estimated with ordinary least squares, and Columns (3) to (8) are estimated as Tobit models. All regressions include *ln(Assets)*, *Foreign asset share*, *ln(GDP)*, *GDP per capita growth*, and year and industry fixed effects. Standard errors are clustered by firm. For each independent variable, the top row shows the estimated coefficient and the bottom row shows the *t*-statistic. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: Scope 1 Emissions

Dependent variable:	ln(1+Global emissions (tons))		ln(1+Home emissions (tons))		ln(1+Foreign emissions (tons))		Foreign emissions in % of global emissions	
Specification:	OLS	OLS	Tobit	Tobit	Tobit	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SER (stringency)	-0.25 ***		-0.47 ***		0.46 **		5.25 ***	
	(-2.71)		(-2.62)		(2.46)		(2.73)	
EER (enforcement)		-0.19 ***		-0.45 ***		0.44 ***		5.44 ***
		(-2.61)		(-3.34)		(2.87)		(3.48)
Controls	yes	yes	yes	yes	yes	yes	yes	yes
Fixed effects								
Year	yes	yes	yes	yes	yes	yes	yes	yes
Industry	yes	yes	yes	yes	yes	yes	yes	yes
Adjusted/Pseudo R-squared	0.692	0.691	0.112	0.113	0.104	0.105	0.051	0.052
Observations	4,919	4,919	4,919	4,919	4,919	4,919	4,919	4,919
of which censored at 0			226	226	481	481	481	481
of which censored at 100							226	226

Panel B: Scope 2 Emissions

Dependent variable:	ln(1+Global emissions (tons))		ln(1+Home emissions (tons))		ln(1+Foreign emissions (tons))		Foreign emissions in % of global emissions	
Specification:	OLS	OLS	Tobit	Tobit	Tobit	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SER (stringency)	-0.30 ***		-0.65 ***		0.57 ***		10.50 ***	
	(-4.38)		(-3.98)		(3.43)		(5.79)	
EER (enforcement)		-0.23 ***		-0.62 ***		0.50 ***		9.89 ***
		(-3.92)		(-4.73)		(3.80)		(6.58)
Controls	yes	yes	yes	yes	yes	yes	yes	yes
Fixed effects								
Year	yes	yes	yes	yes	yes	yes	yes	yes
Industry	yes	yes	yes	yes	yes	yes	yes	yes
Adjusted/Pseudo R-squared	0.594	0.594	0.083	0.084	0.099	0.099	0.053	0.054
Observations	5,018	5,018	5,018	5,018	5,018	5,018	5,018	5,018
of which censored at 0			196	196	430	430	430	430
of which censored at 100							196	196

Appendix Table 3. SER vs. EER (Cont.)

Panel C: Orthogonalized Environmental Enforcement; Scope 1 Emissions

Dependent variable:	ln(1+Global emissions (tons))	ln(1+Home emissions (tons))	ln(1+Foreign emissions (tons))	Foreign emissions in % of global emissions
Specification:	OLS	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)
SER (stringency)	-0.13 ***	-0.24 **	0.24 **	2.66 ***
	(-2.71)	(-2.55)	(2.38)	(2.62)
EER_o (enforcement; orthogonalized)	0.00	-0.19 **	0.18 **	2.90 ***
	(0.02)	(-2.25)	(2.00)	(3.48)
Controls	yes	yes	yes	yes
Fixed effects				
Year	yes	yes	yes	yes
Industry	yes	yes	yes	yes
Adjusted/Pseudo R-squared	0.692	0.113	0.105	0.052
Observations	4,919	4,919	4,919	4,919
of which censored at 0		226	481	481
of which censored at 100				226

Panel D: Orthogonalized Environmental Enforcement; Scope 2 Emissions

Dependent variable:	ln(1+Global emissions (tons))	ln(1+Home emissions (tons))	ln(1+Foreign emissions (tons))	Foreign emissions in % of global emissions
Specification:	OLS	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)
SER (stringency)	-0.16 ***	-0.33 ***	0.30 ***	5.41 ***
	(-4.40)	(-3.92)	(3.37)	(5.74)
EER_o (enforcement; orthogonalized)	0.01	-0.24 **	0.12	3.62 ***
	(0.17)	(-2.53)	(1.61)	(4.06)
Controls	yes	yes	yes	yes
Fixed effects				
Year	yes	yes	yes	yes
Industry	yes	yes	yes	yes
Adjusted/Pseudo R-squared	0.594	0.084	0.099	0.055
Observations	5,018	5,018	5,018	5,018
of which censored at 0		196	430	430
of which censored at 100				196

Appendix Table 4. Subsample Analysis: Only Externally Audited Emission Data

The table presents evidence about the relation between emissions in foreign countries and home-country environmental policies for companies whose emissions information is externally verified. Panels A and B show results for Scope 1 and 2 emissions, respectively. Column (1) is estimated with ordinary least squares, and Columns (2) to (4) are estimated as Tobit models. All regressions include *ln(Assets)*, *Foreign asset share*, *ln(GDP)*, *GDP per capita growth*, and year and industry fixed effects. Standard errors are clustered by firm. SEER is our proxy for stringency and enforcement of environmental regulation in the firm's home country, with higher values indicating stricter regulation. For each independent variable, the top row shows the estimated coefficient and the bottom row shows the *t*-statistic. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: Scope 1 Emissions

Dependent variable:	ln(1+Global emissions (tons))	ln(1+Home emissions (tons))	ln(1+Foreign emissions (tons))	Foreign emissions in % of global emissions
Specification:	OLS	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)
SEER	-0.16 **	-0.37 ***	0.28 **	3.24 **
	(-2.55)	(-3.28)	(2.34)	(2.55)
Controls	yes	yes	yes	yes
Fixed effects				
Year	yes	yes	yes	yes
Industry	yes	yes	yes	yes
Adjusted/Pseudo R-squared	0.739	0.125	0.116	0.052
Observations	3,075	3,075	3,075	3,075
of which censored at 0		122	235	235
of which censored at 100				122

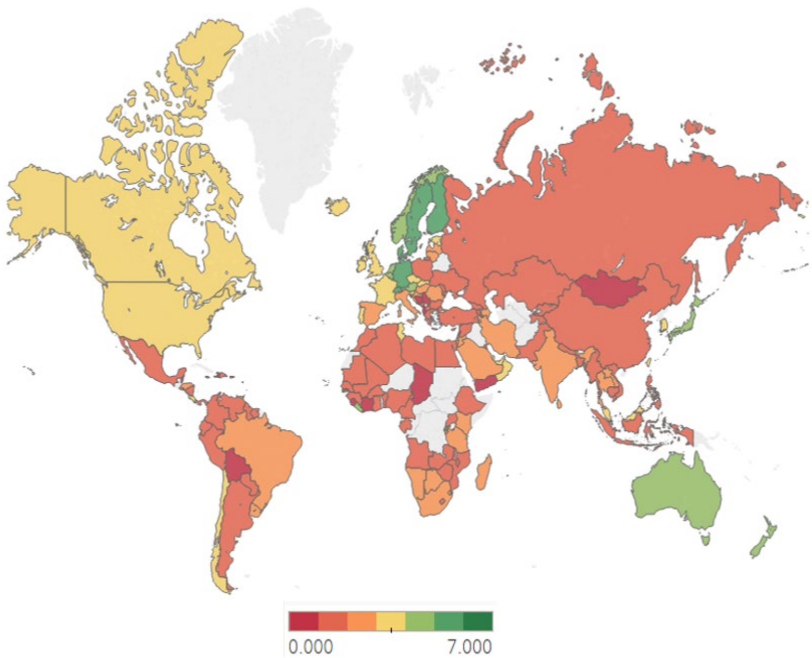
Panel B: Scope 2 Emissions

Dependent variable:	ln(1+Global emissions (tons))	ln(1+Home emissions (tons))	ln(1+Foreign emissions (tons))	Foreign emissions in % of global emissions
Specification:	OLS	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)
SEER	-0.15 ***	-0.41 ***	0.32 ***	6.14 ***
	(-3.13)	(-3.70)	(3.03)	(4.90)
Controls	yes	yes	yes	yes
Fixed effects				
Year	yes	yes	yes	yes
Industry	yes	yes	yes	yes
Adjusted/Pseudo R-squared	0.631	0.076	0.115	0.058
Observations	2,895	2,895	2,895	2,895
of which censored at 0		115	168	168
of which censored at 100				115

Figure 1. Global Development of Environmental Regulation

The heat maps show our proxy for environmental regulation (SEER) for the 150 countries included in our sample as of 2008 in Panel A and 2015 in Panel B. SEER combines the World Economic Forum's assessment of a country's stringency and enforcement of environmental regulation. SEER ranges from 0 to 7, with lower values, colored red, indicating laxer environmental regulation and higher values, colored green, indicating stricter environmental regulation.

Panel A. 2008



Panel B. 2015

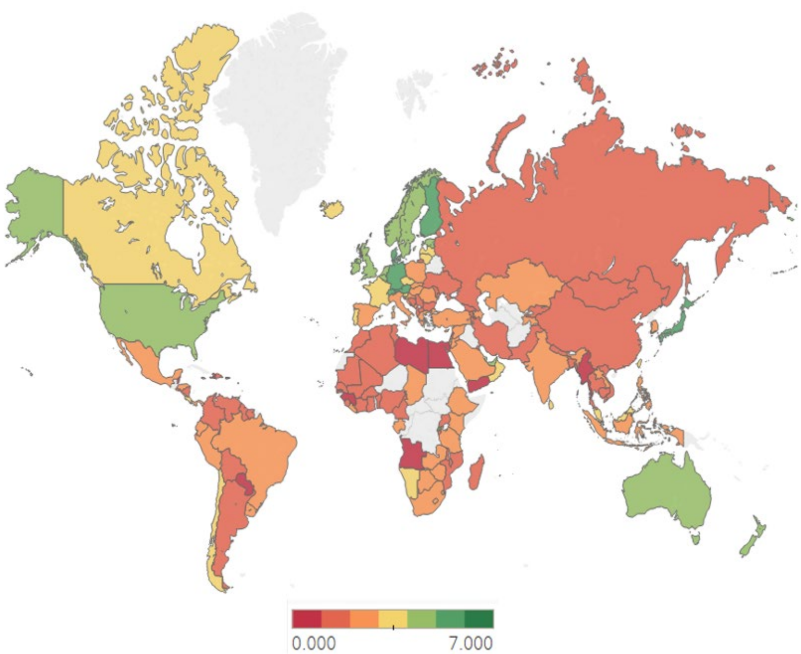


Figure 2. Visualization of the Home and Foreign Emissions with Respect to Cross-Country Environmental Regulation

The figure visualizes the relationship between country-level environmental regulation and CO_2 emissions by multinational firms. We plot each country as a circle, with the size indicating the average home emission amount (in tons) by multinational firms headquartered in that country. The color of the circle represents the score of environmental regulation of each country, measured as SEER, which combines the World Economic Forum's assessment of a country's stringency and enforcement of environmental regulation. SEER ranges from 0 to 7, with red being lower values indicating laxer environmental regulation and green being higher values indicating stricter environmental regulation. The average percentage of CO_2 emissions in foreign countries out of global emissions by the multinational firms headquartered in each country are shown on the y-axis. All numbers are averaged by firms over the 2008-2015 period.

Figure 3. Differences in Environmental Regulation and Emissions in Foreign Countries

The figure presents the differences in environmental regulation and emissions in foreign countries. The sample includes the firm-country-year observations for which SEER in the home and foreign country is known. We exclude the observations with zero emissions. We split the firm-country pairs into three categories based on the difference in environmental regulation in the home versus foreign country. The left, middle, right bar panels in x-axis represent country pairs with stronger ($SEER_{home} - SEER_{foreign} < -1$), similar ($-1 \leq SEER_{home} - SEER_{foreign} < 1$), and weaker ($SEER_{home} - SEER_{foreign} \geq 1$) regulation abroad relative to home country. The y-axis shows average tons of CO_2 emissions to a target foreign country by the multinational firms headquartered in home country per million USD of foreign country's GDP.

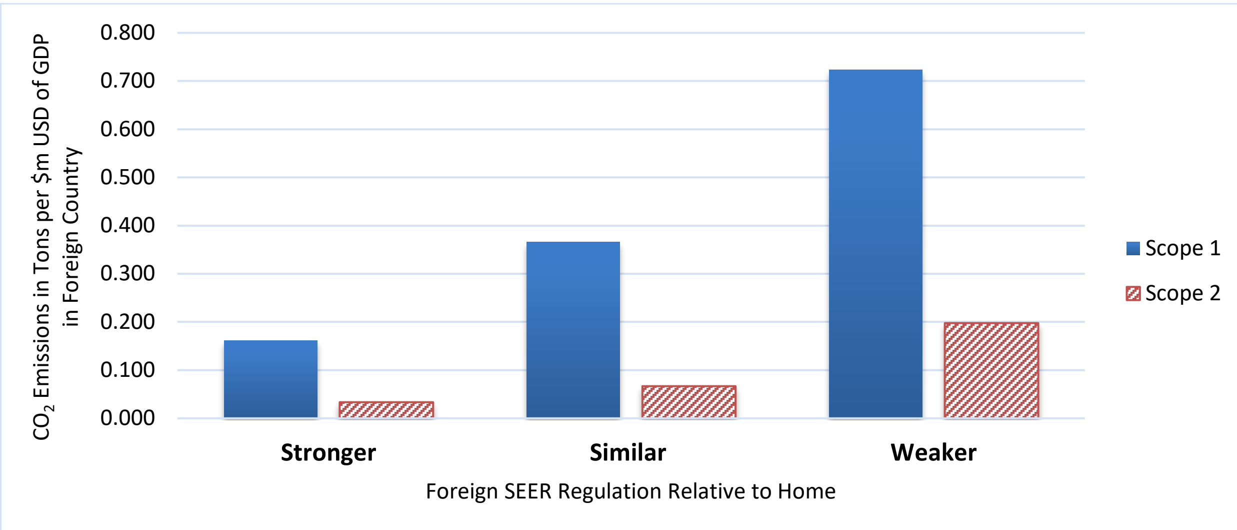
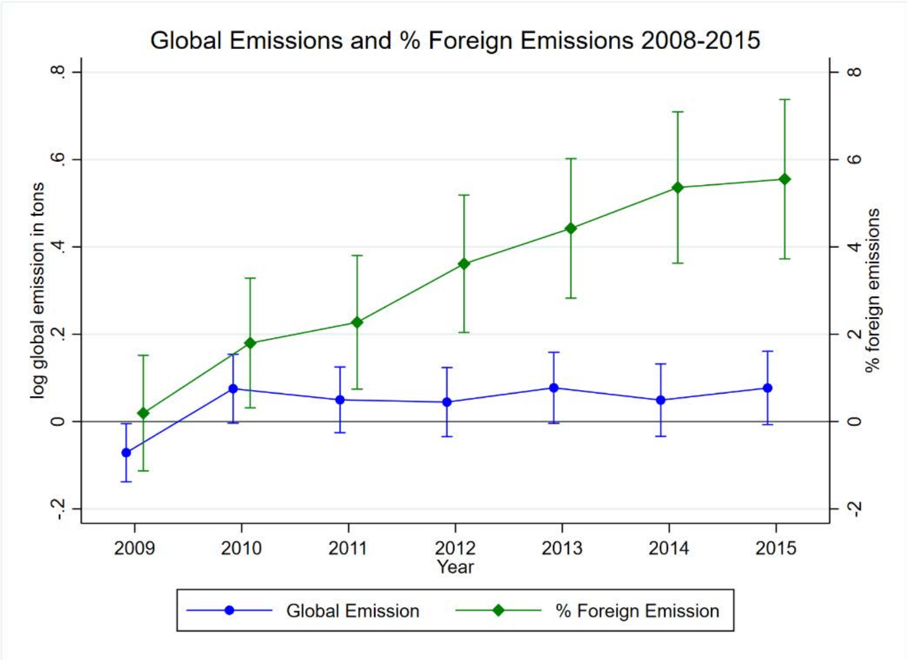


Figure 4. Evolution of Pollution over Time 2008-2015

This figure shows the annual changes of CO_2 emissions by firms in our sample over the period of 2008-2015. The sample includes the firm-country-year observations for which SEER in the home and foreign country is known. We plot the point estimates and 95% confidence intervals of the year dummy variables from the ordinary least square regressions, where the dependent variable is ln(1+Global emissions) and foreign emissions in % of global emissions in Panel A and ln(1+Home emissions) and ln(1+Foreign emissions) in Panel B. All regressions include firm fixed effects. The dependent variables are based on Scope 1 emissions. The coefficients of the year dummy variables indicate the incremental changes in pollution activities over time (2008 as a baseline).

Panel A. Global Emissions and Percet of Foreign Emissions



Panel B. Domestic vs. Foreign Emissions

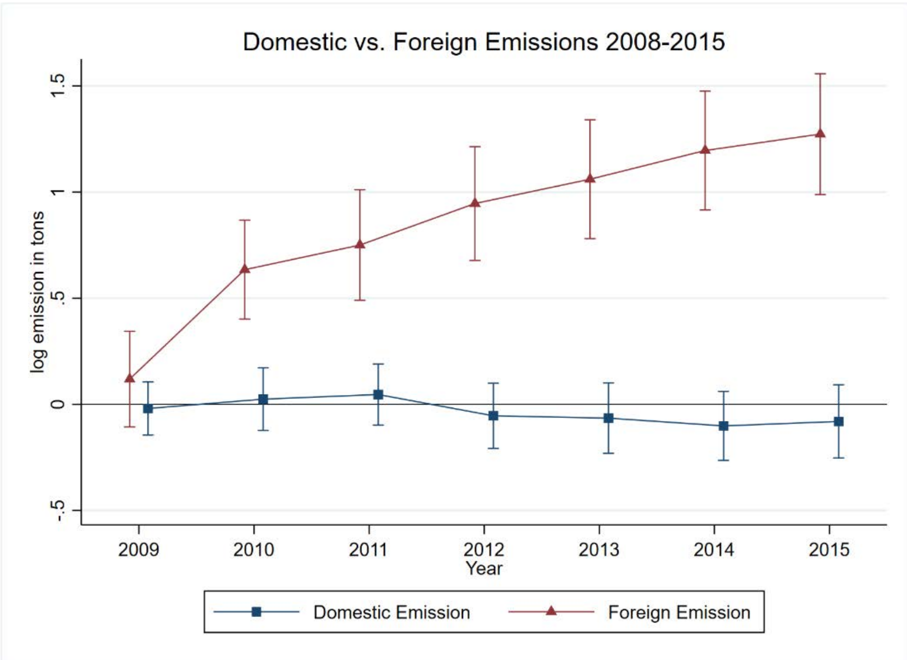


Figure 5. Pollution Intensity by Industry

This chart shows the CO_2 intensity of various industries in the European Union (2018 member states). CO_2 intensity is measured as the kilograms of CO_2 per Euro of gross value added. For comparability over time, gross value added is measured in real terms (chain linked volumes at 2010 prices) to eliminate the effects of inflation. Pollution-intensive industries are marked with striped red bars. Source: Eurostat, Air emission accounts, Air emissions intensities by NACE Rev. 2 activity (env_ac_aeint_r2): http://ec.europa.eu/eurostat/web/environment/emissions-of-greenhouse-gases-and-air-pollutants/air-emission-accounts/database