Exporting Pollution: Where Do Multinational Firms Emit CO_2?

Carbon leakage

SUMMARY

Despite widespread 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 microdata about multinational 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 largely driven by tightened environmental policies in home *countries that incentivize firms to pollute abroad rather than lenient* foreign *policies that attract those firms. Although firms headquartered in countries with strict domestic environmental policies are more likely to export pollution to foreign countries, they nevertheless emit somewhat less overall CO_2 globally.*

JEL codes: F23, N50, O13, P18, Q56, R11

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Economic Policy July 2021 Printed in Great Britain

Exporting pollution: where do multinational firms emit CO_2?

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1. INTRODUCTION

As signs of climate change accumulate, countries around the globe are taking action, yet the strictness of their environmental policies varies significantly.[1] Diversity and lack of

* We are grateful to Carbon Disclosure Project (CDP) for sharing the climate-change data with us. All views expressed in this paper are those of the authors and not necessarily those of the international business of Federated Hermes or EOS at Federated Hermes. We appreciate the helpful comments of Dennis Novy, Eleonora Patacchini and Per Stromberg, and of participants at the 72nd Economic Panel, Sustainable Finance Conference.

The Managing Editor in charge of this paper was Tommaso Monacelli.

1 For example, the European Commission announced in December 2019 a 30-year plan to move towards a climate-neutral economy by 2050, called the European Green Deal, and proposed to enact climate law. Other countries, however, are maintaining laxer regulations and failing to meet lower carbon dioxide (CO_2) emissions targets set forth in the Paris Agreement of 2015, designed to collectively combat climate change (United Nations Environment, 2019). Still others are considering withdrawing from the Paris Agreement altogether. The US withdrew from the Paris Agreement in November 2020, and rejoined in February 2021. The Australian government resisted taking action to increase the 2030 target for CO_2 emissions after catastrophic bushfires in early 2020.

Economic Policy July 2021 pp. 377–437 Printed in Great Britain

coordination in regulations across countries can lead to 'carbon leakage', meaning that firms decide strategically where to locate their production based on existing environmental policies.

Given the heterogeneity in environmental policies across countries, the behaviour of multinational firms is especially important for two main reasons. First, the cost of shifting polluting activities abroad for multinational firms is low relative to the cost that would be incurred by purely domestic firms, as they can utilize existing infrastructure. Second, multinational firms are an important segment of the global economy; for example, cross-border investment by multinational firms contributed 50% of the gross domestic product (GDP) of OECD countries in 2017 (Navaretti and Venables, 2013; Shapiro and Hanouna, 2019).[2] Despite their economic importance, little is known about the extent to which multinational firms allocate polluting activities around the globe in response to environmental policies. Understanding the symbiotic relationship between countries' environmental policies and the production decisions of multinational firms would help policymakers and governments effectively address the emerging challenges from climate change.

In this article, we study the impact of environmental policies on multinational firms' polluting activities both at home and in foreign countries in the 2010s.[3] Although several greenhouse gases contribute to climate change, we focus on carbon dioxide (CO_2), a byproduct of industrial production that has the fastest concentration growth in the atmosphere.[4] Combining firm-level data about their CO_2 emissions in each country and information about the country-level environmental regulations and enforcement, we assess the impact of home versus foreign environmental policies on firms' pollution allocations. Our findings indicate that the allocation of pollution activities is primarily driven by the environmental policies in the home country rather than by the opportunities available to pollute elsewhere. Our findings highlight the importance of collective action to combat climate change given the global scale of firms' operations.

We use a novel panel dataset covering 1,970 large public firms headquartered in 48 countries and their CO_2 emissions in 218 countries during the 2008–15 period. 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, providing direct evidence on the effect of environmental policies and firms' actual CO_2 emissions at the micro-level.

2 The statistics are based on the outward foreign direct investment positions (stocks), as a percentage of GDP, at 2017 year-end for member countries in the Organisation for Economic Co-Operation and Development (OECD). See the OECD International Direct Investment Statistics (database) at https://doi.org/10.1787/idi-data-en.

3 Other studies, such as Kim et al. (2019), explore the causal relation 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.

4 For further information, see https://www.ucsusa.org/global-warming/science-and-impacts/science/CO2-and-global-warming-faq.html.

In the main analysis, 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 domestically relative to firms headquartered in countries with more lenient environmental regulation. However, we find evidence of carbon leakage from countries with strict environmental policies: 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 a 29% reduction of CO_2 emissions at home, but it is also associated with up to a 43% increase in emissions abroad. These results lend support to the concern that strict environmental policies may lead to carbon leakage.

While firms headquartered in countries with tighter policies pollute less domestically and more abroad, there is some evidence that they pollute less globally in aggregate. We find that a one-standard-deviation stricter environmental policy in the home country is associated with a reduction of 441,000 tons of CO_2 emissions, which is equivalent to a 14% reduction in Scope 1 CO_2 emissions for the average firm that emits 3.15 million tons each year. However, when one considers outsourcing some production to other firms, the estimate decreases by half but remains marginally statistically significant.[5] Our analysis, therefore, suggests that stringent domestic environmental policies are associated with a partial, but positive, impact on reducing overall pollution.

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

The results thus far are consistent with the pollution haven hypothesis, suggesting that firms perform their polluting activities in countries with lenient environmental policies. Prior studies examining this hypothesis are based on limited data, for example aggregated at the industry or country levels, or lack actual emissions data.[6]

Our data allow us to dive deeper into the drivers of carbon leakage. We perform three analyses on this account.

5 This latter result, however, should be considered with caution due to data reliability, as we explain in Section 3.2.

6 Earlier studies used limited data aggregated at the industry or country levels (e.g. Eskeland and Harrison, 2003; Cole, 2004; He, 2006; Wagner and Timmins, 2009). Related firm-level studies also provide indirect evidence, *without* observing actual pollution levels, that firms are more likely to have facilities in countries with weak environmental policies (Becker and Henderson, 2000, 2001; Ben Kheder and Zugravu, 2012; Dam and Scholtens, 2012). A few recent studies use actual CO_2 emissions data, but the scope of these studies is limited – within specific countries or industries (e.g. Ederington et al., 2005; Bento et al., 2015; Bartram et al., 2019).

First, a combination of both push and pull forces can explain our baseline results of carbon leakage. The push is evident when firms export their polluting operations to foreign countries in response to tightened environmental regulations in their home countries. The motivation for this move is purely economic because complying with stricter environmental policies is costly, requiring investment in resources such as waste treatment, auditing and litigation (see, e.g. Christainsen and Haveman, 1981; Stewart, 1993). The pulling force is in action when countries deliberately impose relatively weak environmental policies to attract the economic activity of polluting firms. Such countries may benefit, at least in the short run, from the economic growth that additional industrial production would likely bring through employment and investment.

Our analysis shows that the main force dictating multinationals' emission of CO_2 abroad is pressure from the home country's environmental policies (the push force). We start by testing the 'push hypothesis'. We use a specification that holds constant the environmental policies of foreign countries to test whether changes in the environmental policies in the home country have an effect (as in Khwaja and Mian, 2008). Indeed, we find evidence of such a 'push effect': Tightening the home countries' environmental policies pushes multinational firms out and incentivizes them to pollute in foreign countries. Next, we reverse the specification and test the 'pull hypothesis'. We hold constant the home country environmental policies and test whether changes in the foreign country environmental policies matter for pollution abroad. We find no evidence supporting the pull hypothesis. In sum, multinational firms pollute abroad because of the tightening of policies in the home countries, not because of pollution opportunities abroad.

Second, we consider firm-level governance. For firms that 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 strong governance mechanisms guide managers to consider long-term value, providing a counterweight that pushes the firm towards production with lower emissions (see Krueger, 2015, as well as the Dupont case in Shapira and Zingales, 2017).[7]

Third, we consider the variation of pollution by industry. Polluting activities vary widely by industry, and therefore we conduct a cross-sectional analysis by industry type. We document that firms' behaviour with respect to environmental policies is more accentuated in pollution-intensive industries. The emissions in the home country of firms in these industries are less sensitive to home environmental policies; however, their

7 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 institutional investors' perceptions of climate risks in Krueger et al. (2020) and Bonnefon et al., 2019]. Consistent with institutional investors valuing firm environmental profiles, Kim et al. (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.

emissions abroad are twice as sensitive to home policies, relative to firms in other industries. This finding is consistent with the idea that complying with strict environmental policies is particularly costly for firms in pollution-intensive industries.

Overall, our study informs the debate among regulators as well as economists about the effectiveness of environmental policies in reducing pollution and their economic consequences. For regulators, our findings on multinational firms' CO_2 emissions patterns in response to the stringency of countries' environmental policies highlight the need for global coordination of regulations on carbon dioxide emissions. We find that firms increase their pollution abroad in response to the tightening of environmental policies in their home countries, as opposed to being attracted by lax policies abroad. Thus, our results imply that without collective action, 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.

2. DATA DESCRIPTION AND SUMMARY STATISTICS

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, 2020). As of August 2020, more than 500 institutional investors with more than US$100 trillion in assets under management (AUM) were supporting CDP and its initiatives. Since CDP's inception in 2000, the number of institutional investors that have become signatories of CDP has grown tremendously as has the AUM represented by those investors. CDP began by surveying only publicly-traded UK 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 the CO_2 emissions that stem both directly and indirectly from their operations. The answers to these questions allow us to directly measure firm-level emissions and identify the countries where 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 three main measures of CO_2 emissions. Scope 1 emissions are the total CO_2 emissions (in metric tons) that stem directly from the operations of the reporting firm. Scope 2 emissions are the total CO_2 emissions (in metric tons) 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. A third category of CO_2 emission is Scope 3, which measures other indirect emissions such as outsourced activities, business trips and the production from suppliers in the supply chain. Scope 3 emissions data provided by CDP cover a subset of firms during the 2009–13 period and are only available at the aggregate firm level. Until 2011, firms were free to define their own Scope 3 categories. Only from 2012 onwards did CDP ask firms to disclose standard sources for Scope 3 emissions.[8] In addition to the lack of standardization in the reported data, only about 40% of firms report Scope 3 emissions (816 out of 1,970).[9] Because of these data issues, results based on Scope 3 data should be interpreted with caution.

Note that our data are based on firms' self-reported information. Specifically, 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 pressure 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 to understand the long-run implications of tightening climate change and environmental regulations resulting from the Paris Agreement on climate change, which was agreed upon at the end of 2015 and subsequently has begun to be 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 that 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 et al., 2016). Finally, a self-reporting bias is likely

8 These categories included business travel, purchased goods and services, waste generated in operations, capital goods, downstream transportation and distribution, employee commuting, fuel- and energy-related activities (not included in Scope 1 or 2), downstream leased assets, end-of-life treatment of sold products, franchises, investments, other (downstream), other (upstream), processing of sold products, upstream leased assets, upstream transportation and distribution, use of sold products, purchased goods and services, upstream transportation and distribution and fuel- and energy-related activities (not included in Scope 1 or 2).

9 We have not found, however, any systematic bias (e.g. industry, firm size) in the type of firms that report Scope 3 emissions.

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.[10] We use this fact to provide some assurance regarding the quality of the data and hence the results.[11]

2.2. Country-level data: environmental laws, enforcement and macroeconomic conditions

We use an additional dataset compiled by the World Economic Forum (WEF) that contains information about the strictness of environmental laws and enforcement at the country-year level. This dataset covers the 2008–15 period and is publicly available on a bi-annual basis for 150 countries.[12] WEF assigns two rankings for each country on a scale from 1 to 7—(1) the stringency of its environmental regulation (SER) and (2) how strictly these laws are enforced (EER), based on surveys of top local business leaders.[13] The profile of the survey respondents 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

10 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 their reported information on carbon emissions has been verified and, if so, by whom.

11 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 obtained using the full sample. We discuss these robustness tests and results in Section 5.2.

12 See The Travel & Tourism Competitiveness Reports of WEF, for example https://www.weforum.org/reports/the-travel-tourism-competitiveness-report-2017.

13 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.

environmental policy measures—stringency of environmental regulation and stringency of enforcement—are highly correlated (correlation coefficient of 0.97).

For our analysis, we combine the two policy measures into 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 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: $\text{SEER} = \frac{1}{7}\text{SER} \times \text{EER}$. We call this measure stringency and enforcement of environmental regulation, or SEER, and its value ranges from 0.14 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 5.1. Overall, our results largely remain robust across the three methods.

To consider macroeconomic conditions of the countries in which firms operate, we collect information on GDP and GDP per capita growth from the World Bank's World Development Indicators. We also estimate the industry-level comparative advantage in skilled labour and capital of each country—CA (Skill) and CA (Capital), respectively—following Romalis (2004) and Nunn (2007).[14] CA (Skill) is defined as $h_s H_c$ and CA (Capital) is defined as $k_s K_c$. H_c and K_c denote endowment in skilled labour and capital in country c, respectively. h_s and k_s denote the skill and capital intensities of production in the firm's industry s.[15] Skill intensity h_s is the ratio of nonproduction worker wages to total wages in industry s in the United States, averaged across the period 2008–11. Capital intensity k_s is the real capital stock in industry s divided by the value added in industry s in the United States, averaged across the period 2008–11. A country's skilled labour endowment H_c is measured as the natural log of the ratio of the population aged 25 years or above that completed secondary education to those that did not complete secondary education.[16] A country's capital endowment K_c is the natural log of the capital stock per worker, averaged across the period 2008–15.[17] 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 Andrew Rose's website (see Glick and Rose, 2016) and the International Monetary Fund's Direction of Trade Statistics.

14 Skilled labour and capital endowment data are not available for all countries, and factor intensities are only available for manufacturing industries. Consequently, our sample size drops substantially.

15 Data for factor intensities are obtained from the NBER-CES Manufacturing Industry Database available at http://data.nber.org/nberces/, which contains annual data up to 2011.

16 Data for skilled labour endowment H_c are obtained from the Barro–Lee Educational Attainment Dataset, available at http://barrolee.com/. Data for 2010 are used as this is the only year that falls into our sample period.

17 Data for capital endowment K_c are obtained from the Penn World Tables, available at https://www.rug.nl/ggdc/productivity/pwt/.

2.3. Firm-level financial data

We obtain firm-specific financial information, including total assets and foreign asset share, from Worldscope. As our measure of the corporate governance quality of firms, we use the corporate governance score provided in the Thomson Reuters Asset4 database (*CGVSCORE*). This firm-year dataset is widely used in academic research as well as by long-term institutional investors interested in environmental, social and governance 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. All variable definitions and sources can be found in Appendix Table A1.

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.[18] The final dataset includes 1,970 large public firms headquartered in 48 countries and their CO_2 emissions in 150 countries during the 2008–15 period.[19]

2.4. Summary statistics

2.4.1. Trends in pollution and environmental policies. Table 1 reports summary statistics over the sample period of 2008–15, including the number of unique firms, their global and home-country emissions, and the number of countries in which each firm has emissions. In Panels A and B, for the average firm, global Scope 1 and Scope 2 emissions in tons decrease over time. Note that the majority of emissions are direct Scope 1 emissions. In Panel C, global Scope 3 emissions are much larger in scale as they include all relevant indirect emissions across supply chains. 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. Most CO_2 is emitted domestically, but the share of home emissions in global emissions decreases substantially over time (from 72% in 2008 to about 57% in 2015 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).

The multinational firms reporting to CDP are not necessarily representative of the universe of multinational firms.[20] We explore the extent of their differences from the

18 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.

19 Our analysis using a firm–country–year panel is limited to the 150 countries for which environmental policy scores (SEER) are available.

20 We define as multinational the firms that report non-missing foreign income in the previous 3 years.

Table 1. Summary statistics

Panel A: Scope 1 emissions

Year	Number of firms	Average across firms: Firm's global emissions in metric tons	Firm's emissions in home country as a % 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

Year	Number of firms	Average across firms: Firm's global emissions in metric tons	Firm's emissions in home country as a % 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

Panel C: Global scope 1 and 3 emissions for a subsample with Scope 3 available

Year	Number of firms	Average across firms: Firm's Scope 1 global emissions in metric tons	Firm's Scope 3 global emissions in metric tons	Environmental regulation (SEER) in firm's home country
2009	18	4,788,701	4,048,679	4.2
2010	603	2,864,831	10,041,518	4.1
2011	715	3,039,174	16,276,058	4.2
2012	753	3,287,499	15,204,653	4.2
2013	719	3,205,202	14,758,594	4.2

Panel D: Comparing multinational firms reporting to CDP to the universe of multinational firms

Year	% firm-year observation	% aggregated total assets	% aggregated market capitalization	% institutional ownership
2008	10.8%	44.4%	39.3%	35.0%
2009	14.4%	62.7%	50.8%	48.9%
2010	14.4%	61.7%	51.0%	48.8%
2011	16.3%	64.2%	52.5%	50.7%
2012	19.2%	67.6%	55.0%	51.4%

(*continued*)

Table 1. Continued

Panel D: Comparing multinational firms reporting to CDP to the universe of multinational firms

Year	% firm-year observation	% aggregated total assets	% aggregated market capitalization	% institutional ownership
2013	20.8%	68.6%	55.8%	51.1%
2014	25.0%	67.0%	58.0%	54.1%
2015	27.6%	68.5%	60.3%	55.7%

Panel E: Stringency and enforcement of environmental regulation (SEER)

						Average across firms (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

Notes: The table shows descriptive statistics on the Scope 1, 2 and 3 CO_2 emissions and environmental regulation proxies by year from 2008 to 2015. Statistics are based on the sample of all firms that report at least 85% of their global emissions on a country level and that are headquartered 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 WEF's assessment of a country's stringency and enforcement of environmental regulation. The proxy ranges from 0.14 to 7, with higher values indicating stricter environmental regulation. We show the descriptive statistics of Scope 1 and Scope 2 emissions by year in Panels A and B, respectively. Panel C includes the summary statistics of Scope 3 emissions and only includes a subsample of firm–year observations for which Scope 3 information is available. In Panel D, we compare the firms that report emissions data to CDP to the rest of the multinational firms in Worldscope; firms are defined as multinational if they report non-missing foreign income at least once in the previous 3 years. In Panel E, we show the descriptive statistics of the environmental regulation index (SEER) by year.

universe of multinational firms in Worldscope and compare a few key differences in Table 1, Panel D. Our dataset includes only 18.1% of the firms in Worldscope. However, their economic importance amounts to 64.3% of the total assets and 53.9% of the market capitalization reported by Worldscope. A key difference that explains the selection into CDP is institutional ownership. The firms in CDP have higher institutional ownership than their relative share in Worldscope: CDP firms concentrate 50% of the total institutional capital that is invested in multinational firms worldwide. Since institutional investors care about pollution metrics, especially in recent years, pollution figures in our data are likely to be an underestimate of pollution by non-reporting firms. When interpreting our results, readers should bear this non-representativeness in mind.

As described earlier, our measure of environmental regulation is SEER, which is the product of measures of the environmental strictness score (ranging from 1 to 7) and the environmental enforcement score (ranging from 1 to 7), scaled by 7. Panel E of Table 1 indicates that SEER slightly 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. The statistics suggest that environmental regulation has tightened over time, but the cross-country variation is much starker than the time-series variation within a country. Furthermore, we observe that the distribution of environmental regulation is skewed, with most countries being weakly regulated.

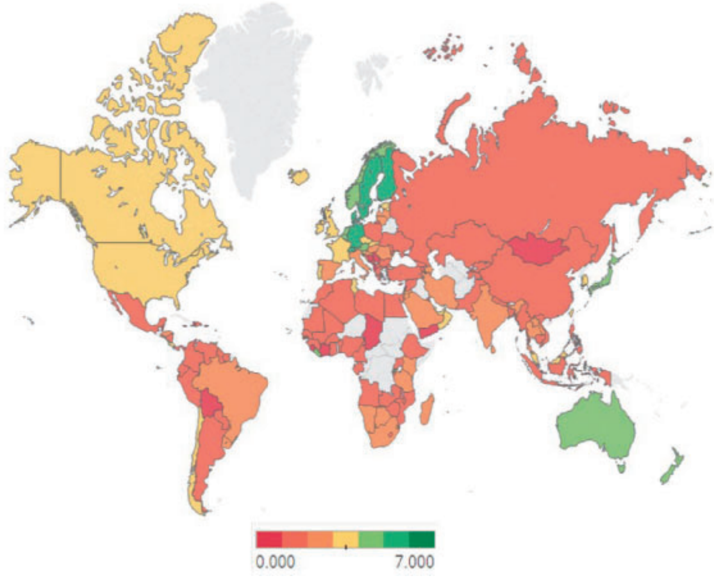
Environmental regulation varies greatly around the globe. Figure 1 uses heat maps to show country-level environmental regulation at the beginning and end of our sample period (2008 and 2015). The maps show a general improvement in environmental regulation over time; however, it remains weak in several large regions, especially in developing countries in Africa, South America and Asia.

As environmental regulations have, on average, tightened globally in recent years, it is important to examine how polluting 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 ordinary least squares (OLS) regressions with time-fixed effects, using the sample of firm-year emissions observations. The dependent variables include the CO_2 emissions variables. In addition to year indicators, we include firm-fixed effects in the regressions to address any potential sample bias from the increase in coverage of firms by CDP. Thus, the coefficients of the year dummy variables indicate the incremental changes in emissions 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.

In Figure 2, we plot the point estimates and 95% confidence intervals of year indicators for global, home, and foreign emissions and the percentage of foreign emissions. In Panel A, we observe a rise in global emissions in 2010; thereafter, global emissions remain relatively constant. However, the percentage of foreign emissions increases over time. Panel B, which focuses on the allocation of pollution between home and foreign countries, clearly confirms this pattern. We find that firms continuously increased the fraction of pollution they export to foreign countries from 2008 to 2015 while moderately reducing pollution at home. These figures imply that global carbon emissions by firms neither increased nor decreased substantially during the study period, but carbon leakage became more prevalent.

2.4.2. Relationship between environmental regulation and CO_2 emissions. Figure 3 presents a visualization of the relation 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 colour 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 headquartered in strictly regulated countries produce a higher proportion of their CO_2 emissions abroad than domestically.

A 2008



B 2015

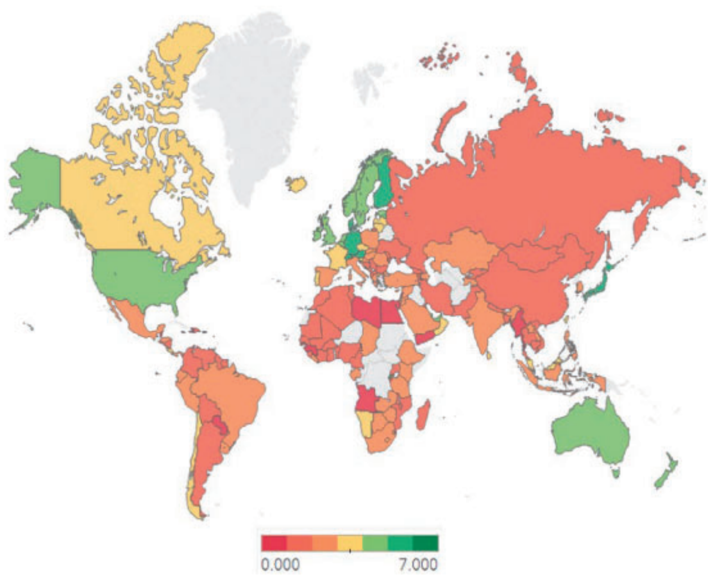
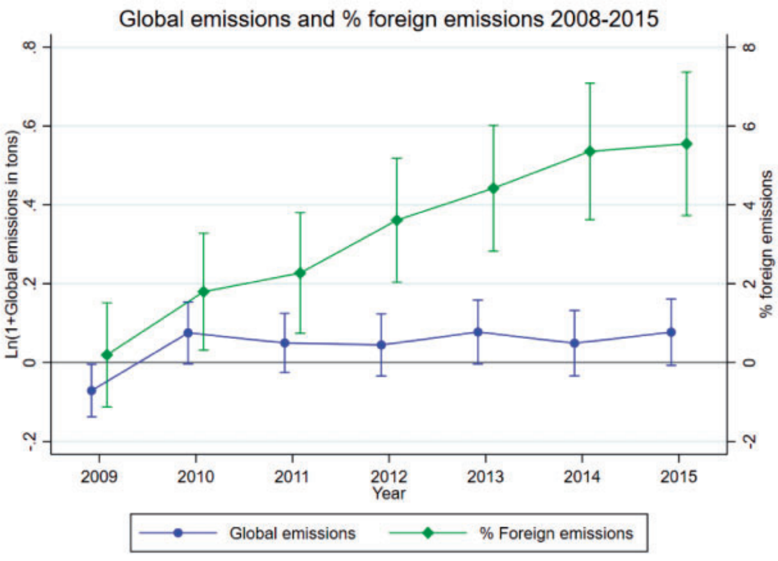


Figure 1. Global development of environmental regulation

Notes: 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 WEF's assessment of a country's stringency and enforcement of environmental regulation. SEER ranges from 0.14 to 7, with lower values, coloured red, indicating laxer environmental regulation and higher values, coloured green, indicating stricter environmental regulation.

A Global Emissions and Percentage of Foreign Emissions



B Domestic versus Foreign Emissions

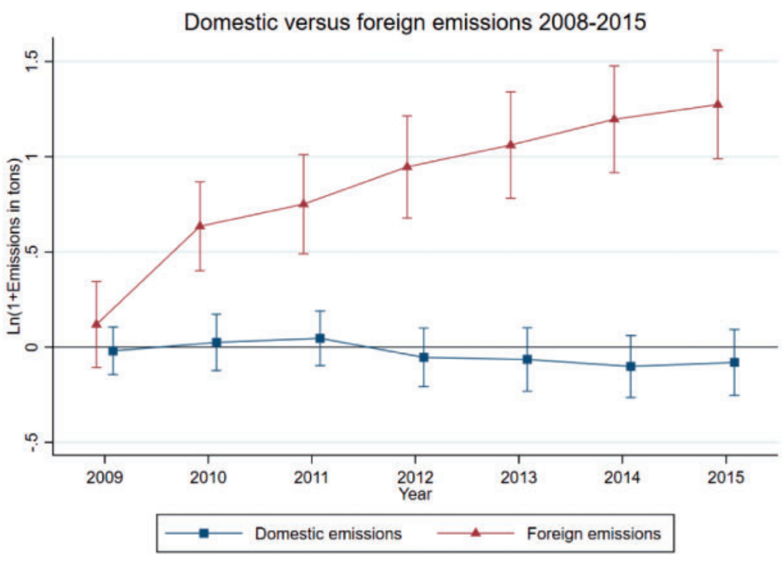


Figure 2. Evolution of pollution over time 2008–2015

Notes: This figure shows the annual changes in CO_2 emissions by firms in our sample over the period of 2008–15. 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 OLS regressions, where the dependent variable is ln(1 + Global emissions) and foreign emissions as a percentage of global emissions in Panel A and is 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).

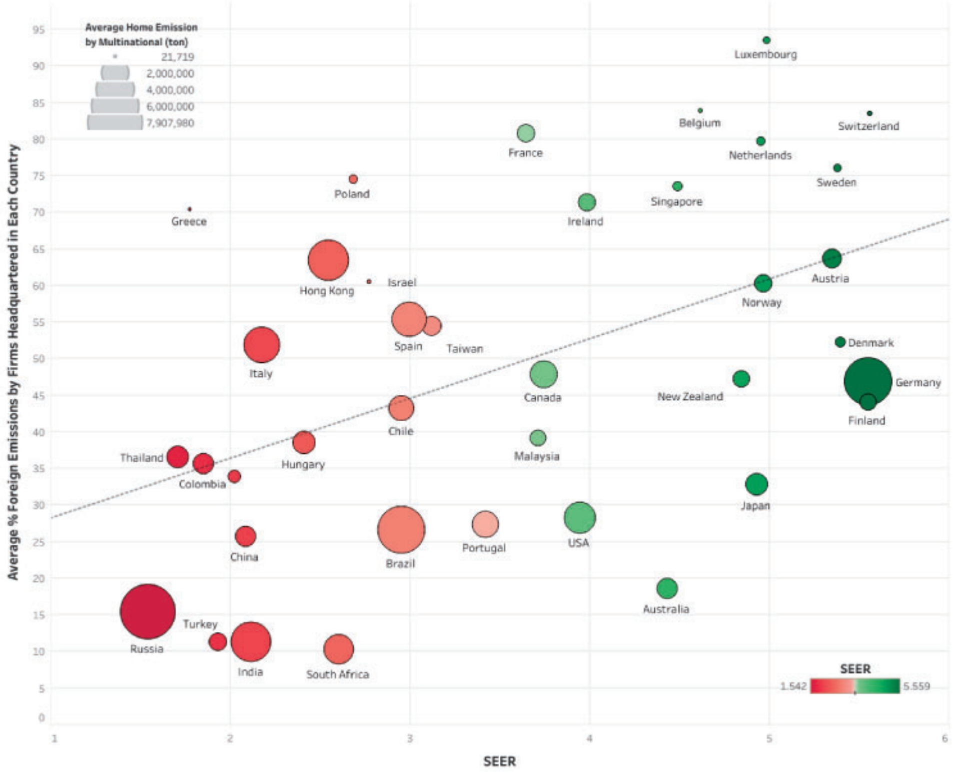


Figure 3. Visualization of home and foreign emissions with respect to cross-country environmental regulation

Notes: The figure visualizes the relation 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 emissions amount (in tons) by multinational firms headquartered in that country. The colour of the circle represents the score of environmental regulation of each country, measured as SEER, a country's stringency and enforcement of environmental regulation. SEER ranges from 0.14 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 is shown on the *y*-axis. All numbers are averaged by firms over the 2008–15 period.

2.4.3. 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 versus 1.30 million tons for Scope 1 emissions and 0.37 million tons versus 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—41.4% for Scope 1 and 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.

Table 2. Descriptive statistics

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
Scope 3 CO_2 emissions						
Global emissions ('000 tons)	2,707	14,672.47	111,383.38	0.00	63.30	4,736,002.50
Environmental regulation in firm's home country						
SEER (0.14–7)	7,016	4.11	0.90	1.07	4.00	6.04
SER (1–7)	7,016	5.43	0.56	2.90	5.38	6.63
EER (1–7)	7,016	5.23	0.68	2.58	5.23	6.41
Firm characteristics						
Assets ($m)	7,016	60.70	194.00	0.31	8.83	1,485.05
Foreign asset share (%)	5,417	26.40	26.15	0.00	17.54	98.77
Corporate governance score (0–100)	6,086	65.07	28.11	1.55	76.53	97.67
Home country characteristics						
GDP ($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
CA(Skill)	3,146	0.61	0.52	−0.86	0.49	2.10
CA(Capital)	3,146	12.37	8.18	1.96	10.15	80.23

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						
$SEER_{ht}-SEER_{ct}$	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
CA(Skill)	299,089	−0.18	0.67	−3.35	−0.16	2.25
CA(Capital)	330,921	10.97	7.50	1.49	8.92	84.28
Home country characteristics						
CA(Skill)	337,094	0.66	0.53	−0.57	0.50	2.10
CA(Capital)	337,094	12.19	8.18	1.96	9.78	80.23
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

Notes: The table presents descriptive statistics for Scope 1, 2 and 3 CO_2 emissions variables, the stringency and enforcement of the environmental regulation (SEER) variable, and the firm-level and country-level variables that are used in the empirical analyses that follow. Summary statistics are based on a firm–year panel in Panel A and a firm–country–year panel in Panel B. The definitions of all variables are provided in Appendix Table A1.

3. EMPIRICAL DESIGN AND MAIN RESULTS

3.1. Polluting domestically or abroad?

To test whether firms pollute more in countries with weak environmental policies, we estimate the following equation:

$$y_{it} = \beta_1 \text{SEER}_{ht} + \beta_2 \text{Controls}_{it} + \sigma_{st} + \varepsilon_{it}.$$

The following dependent variables measure the amount of pollution by firm i in year t: 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.[21] Our main variable of interest is SEER_{ht}, the combined variable capturing environmental policy and enforcement strictness in the firm's home country h in year t. We include as control variables logged firm assets, the share of foreign assets and logged GDP in the home country. In addition, to capture any industry-specific trends in emissions that might confound the changes in country-level regulations targeting specific industries, we include industry-year (σ_{st})fixed effects. Standard errors are clustered by firm.[22]

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 14% decrease in direct global emissions after controlling for firm size, home-country characteristics and industry-year fixed effects.[23] 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 14% reduction amounts to 441,000 fewer tons of CO_2 emitted 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 labour costs or closeness to customers. Due to the limited availability of the foreign asset share variable, the number of

21 We add one to all emissions variables before logging them.

22 As an alternative specification, we also include country-fixed effects in the equation, which produces weakly significant coefficients for foreign emissions (results are available upon request). Given that the time-series variation in SEER within a country is small, our main results can be interpreted as the impact of cross-country differences in SEER.

23 $\%\Delta y = 100 * (e^{\beta * \Delta x} - 1) = 100 * (e^{-0.17 * 0.9} - 1) = -14.19\%$.

Table 3. Analysis of firm-level emissions: effect of domestic environmental policies

Dependent variable:	ln(1 + Global emissions)		ln(1 + Home emissions)		ln(1 + Foreign emissions)		Foreign emissions as a % of global emissions	
Specification:	OLS (1)	OLS (2)	Tobit (3)	Tobit (4)	Tobit (5)	Tobit (6)	Tobit (7)	Tobit (8)
Panel A: Scope 1 emissions								
$SEER_{ht}$	−0.17***	−0.15**	−0.38***	−0.31***	0.40***	0.28***	4.46***	3.24***
	(−3.40)	(−2.53)	(−4.24)	(−2.90)	(3.90)	(2.61)	(4.00)	(2.77)
Firm characteristics								
ln(Assets)	1.04***	1.05***	1.00***	1.08***	1.41***	1.29***	3.74***	1.66**
	(27.10)	(26.00)	(15.68)	(15.84)	(19.42)	(18.36)	(4.80)	(2.28)
Foreign asset share (%)		0.00		−0.03***		0.04***		0.62***
		(0.19)		(−7.49)		(11.49)		(16.69)
Home country characteristics								
ln(GDP)	0.03	0.01	0.44***	0.33***	−0.42***	−0.18**	−8.43***	−5.24***
	(0.71)	(0.22)	(6.24)	(3.98)	(−5.77)	(−2.53)	(−10.93)	(−6.43)
GDP per capita growth	0.02	0.01	0.05	0.03	−0.18***	−0.14***	−1.81***	−1.25***
	(1.05)	(0.60)	(1.39)	(0.67)	(−4.39)	(−3.26)	(−4.24)	(−3.07)
Fixed effects								
Industry × Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted/pseudo *R*-squared	0.697	0.684	0.114	0.121	0.106	0.122	0.0342	0.0569
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

(continued)

Table 3. Continued

Dependent variable:	ln(1 + Global emissions)		ln(1 + Home emissions)		ln(1 + Foreign emissions)		Foreign emissions as a % of global emissions	
Specification:	OLS (1)	OLS (2)	Tobit (3)	Tobit (4)	Tobit (5)	Tobit (6)	Tobit (7)	Tobit (8)
Panel B: Scope 2 emissions								
$SEER_{ht}$	−0.20***	−0.18***	−0.48***	−0.43***	0.41***	0.34***	7.35***	6.60***
	(−5.00)	(−4.15)	(−5.78)	(−4.38)	(4.34)	(3.59)	(6.87)	(5.95)
Firm characteristics								
ln(Assets)	0.92***	0.94***	0.79***	0.88***	1.31***	1.21***	4.44***	2.61***
	(28.70)	(26.92)	(14.09)	(14.42)	(19.95)	(19.58)	(6.06)	(3.85)
Foreign asset share		−0.00		−0.03***		0.03***		0.61***
		(−1.30)		(−8.18)		(10.67)		(17.61)
Home country characteristics								
ln(GDP)	0.08***	0.06*	0.52***	0.41***	−0.28***	−0.11*	−8.55***	−5.51***
	(2.65)	(1.94)	(7.95)	(5.56)	(−4.36)	(−1.66)	(−11.31)	(−7.02)
GDP per capita growth	0.02	0.01	0.04	0.02	−0.19***	−0.12***	−1.78***	−1.08***
	(1.30)	(0.74)	(1.22)	(0.56)	(−4.66)	(−3.04)	(−4.21)	(−2.80)
Fixed effects								
Industry × Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted/pseudo R-squared	0.579	0.583	0.0789	0.0904	0.0955	0.116	0.0373	0.0590
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 3. Continued

Panel C: Scope 3 emissions

Dependent variable:	ln(1 + Scope 1 Global emissions)		ln(1 + Scope 3 Global emissions)		ln(1 + Scope 1 + Scope 3 Global emissions)	
Specification:	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)	OLS (6)
$SEER_{ht}$	−0.24***	−0.19**	0.07	0.12	−0.12*	−0.10
	(−3.75)	(−2.56)	(0.75)	(1.15)	(−1.94)	(−1.28)
Firm characteristics						
ln(Assets)	1.09***	1.15***	1.24***	1.31***	1.16***	1.24***
	(25.04)	(23.64)	(18.50)	(17.37)	(23.90)	(23.28)
Foreign asset share		0.00		−0.00		−0.00
		(0.99)		(−0.87)		(−0.71)
Home country characteristics						
ln(GDP)	−0.02	−0.02	−0.16**	−0.20**	−0.13***	−0.16***
	(−0.38)	(−0.42)	(−2.29)	(−2.42)	(−2.68)	(−2.89)
GDP per capita growth	0.04	0.02	0.02	0.02	0.07**	0.06
	(1.39)	(0.52)	(0.36)	(0.30)	(2.01)	(1.53)
Fixed effects						
Industry × Year	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	2,426	1,852	2,426	1,852	2,426	1,852
Observations	0.737	0.733	0.417	0.426	0.638	0.636

Notes: The table presents evidence about the relation between global, home and foreign emissions and home-country environmental policies. Panels A–C show results for Scope 1, 2 and 3 emissions, respectively. The regressions are conducted on a firm–year panel. In Panels A and B, Columns (1) and (2) are estimated with OLS in which the dependent variable is ln(1 + Global emissions). Columns (3)–(8) are estimated using a Tobit model. The dependent variable is ln(1 + Home emissions) in Columns (3) and (4), ln(1 + Foreign emissions) in Columns (5) and (6) and Foreign emissions as a % of global emissions in Columns (7) and (8). In Panel C, the sample includes the firm–year observations for which Scope 3 information is available. Columns (1)–(6) are estimated with OLS. The dependent variable is ln(1 + Scope 1 Global emissions) in Columns (1) and (2), ln(1 + Scope 3 Global emissions) in Columns (3) and (4) and ln(1 + Scope 1 + Scope 3 Global emissions) in Columns (5) and (6). SEER is our proxy for stringency and enforcement of environmental regulation in the firm's home country, with higher values indicating stricter regulation. All regressions include industry–year fixed effects. Standard errors are clustered by firm. The definitions of all variables are provided in Appendix Table A1. 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.

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 direct global emission levels in either direction.

Overall, these results do not support the commonly held view that an individual country with strict environmental policies can have little impact on direct global pollution levels. Our findings so far suggest that stringent national environmental standards can have a positive impact on curbing firms' global pollution. Firms headquartered in highly regulated countries pollute less globally, potentially due to the environmental standards imposed by the home country. We expand and refine this conclusion in Section 3.2, where we further consider potential outsourcing activities.

We next test whether the strictness of home-country regulations is related to the geographic allocation of polluting 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, Panels A and B. Because some firms have zero emissions in their home countries, we use a Tobit model for this specification.[24] Here, the effect is larger: A one-standard-deviation increase in SEER is associated with up to a 29% decrease in Scope 1 emissions at home.[25] By contrast, a one-standard-deviation increase in the strictness of environmental policies at home is associated with up to a 43% increase in Scope 1 emissions abroad.[26] As for Scope 2 emissions, Panel B shows that a one-standard-deviation increase in SEER is correlated with a 54% decrease in home emissions and a 45% increase in foreign emissions.[27] 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 United States in the form of the Clean Air Act led 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) and (8) of Panels A and B, we reaffirm the previous findings by documenting the relation between environmental regulation and foreign emissions as a percentage share of total direct global emissions. Specifically, a one-standard-deviation increase in the strictness of domestic environmental policies is associated with a 4.0% greater share of foreign emissions.[28] The result for Scope 2, in Panel B, shows a larger

24 Because the fraction of observations that is censored is relatively low in our sample, we re-estimate all Tobit regressions in Tables 3–5 and Appendix Tables A3 and A4 as OLS. The results remain similar in the alternative specification, and they can be provided upon request.

25 From Column (3): $100 * (e^{-0.38 * 0.9} - 1) = -29.0\%$.

26 From Column (5): $100 * (e^{0.40 * 0.9} - 1) = 43.3\%$.

27 For Column (3): $100 * (e^{-0.48 * 0.9} - 1) = -54.0\%$; for Column (5): $100 * (e^{0.41 * 0.9} - 1) = 44.6\%$.

28 $4.46\% * 0.9 = 4.0\%$.

corresponding effect of 6.6%.[29] As foreign Scope 1 (Scope 2) emissions amount to 38.3% (42.8%) of total direct global emissions for the average firm in our sample, these effects are substantial and economically meaningful.

The changes in pollution in response to strict environmental regulations can be driven by expanding and retracting operations or by changes in technologies that make production more environmentally friendly. To untangle these possible explanations, we use alternative pollution variables that measure the firm's emission efficiency, for example the amount of CO_2 emitted per dollar of operation. Using the subset of firms that report the percentage of foreign assets, we scale CO_2 emissions in tons in home countries (foreign countries) by home assets (foreign assets) in dollar terms. The changes in the pollution efficiency can be interpreted as an improvement in production technologies, rather than stemming from the relocation of operations. The results are reported in Appendix Table A2. The coefficients on SEER are negative for home emissions efficiency, but positive for foreign emission efficiency. These results confirm our main finding that firms under strict environmental policies pollute less at home but more in foreign countries per dollar of assets in home and foreign countries.

3.2. Global emissions and substitution along the supply chain

The findings in Table 3, Panels A and B, show that firms headquartered in countries with stricter environmental policies emit less CO_2 globally directly from their operations. In this section, we broaden the scope of firms' CO_2 emissions and explore the impact of environmental policies on pollution along firms' supply chains. There are two competing hypotheses. First, firms headquartered in countries with tight environmental policies could have a positive spillover effect on their suppliers by demanding that their suppliers reduce their carbon footprint. On the other hand, they may comply with their strict home countries' environmental policies by outsourcing polluting activities, that is, by substituting their own direct pollution with indirect pollution of other firms in their supply chains.

We provide some evidence about global emissions by using Scope 3 information, which broadly records emissions that take place up- and downstream in the firm's supply chain. As discussed in Section 2.1, our dataset contains Scope 3 data only for 2009–13 and for only about 40% of the firms. Further, because of the lack of standardization in the Scope 3 data collection process, especially in the early years, we suggest that our results be interpreted with caution.

Table 3, Panel C, presents the tests. In Columns (1) and (2), we rerun the baseline regressions, which repeat the regressions in Panel A, Columns (1) and (2), for the subsample of firm-years that report Scope 3 emissions data. Our estimates show that the association of SEER with Scope 1 global emissions is stronger by 25–50%, relative to the original results. Then, in Columns (3) and (4), we regress Scope 3 emissions on SEER for the same firm-year observations. The coefficient is positive, though not statistically

29 7.35% * 0.9 = 6.6%.

significant. Finally, in Columns (5) and (6), we combine Scope 1 and 3 emissions into a single dependent variable: combined direct and indirect global emissions.

Our findings provide some weak support for the substitution hypothesis. The results show that when combining direct and indirect global emissions, multinationals headquartered in countries with strict environmental policies emit nearly as much CO_2 as multinationals headquartered in countries with lax policies. These results are consistent with multinationals not only 'exporting' pollution to foreign countries, but also 'outsourcing' it to upstream suppliers. Again, these results should be interpreted with caution given the data quality issues discussed above.

3.3. Where do firms emit CO_2?

We next examine where firms pollute. The analysis in this section 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, this disaggregated model allows us to determine how the difference 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 difference between domestic environmental policies and those abroad.

Figure 4 provides an intuitive visualization of our approach using a firm–target country pair analysis. We focus on the emissions of firm i in foreign country c in year t, and only include the observations for which the SEER scores in the home and foreign country are known.[30] The variable of interest is the difference between the SEER of firm i's home country h 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 figure 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 favourable to them.

To implement the analyses with the firm–country–year panel 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

30 We additionally drop observations of firms with zero emissions in foreign country c in year t to avoid zero-emission observations from affecting the magnitude of average estimates.

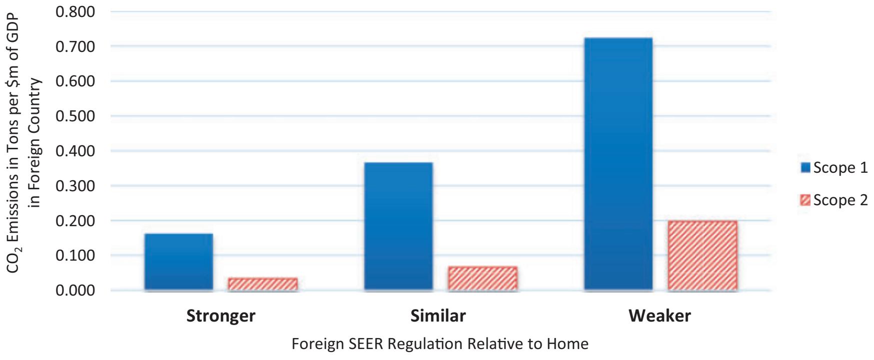


Figure 4. Differences in environmental regulation and emissions in foreign countries

Notes: 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 and right bar panels on the *x*-axis represent country pairs with stronger ($SEER_{ht} - SEER_{ct} < -1$), similar ($-1 \leq SEER_{ht} - SEER_{ct} < 1$) and weaker ($SEER_{ht} - SEER_{ct} \geq 1$) regulation abroad relative to the home country, respectively. The *y*-axis shows average tons of CO_2 emissions to a target foreign country by the multinational firms headquartered in the home country per million USD of the foreign country's GDP.

in year t as long as firm i reports non-zero global CO_2 emissions in a given year t. 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.[31] 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.

Using the firm–country–year panel data, we estimate the following equation:

$$y_{ict} = \beta_1(\text{SEER}_{ht} - \text{SEER}_{ct}) + \beta_2\text{Controls}_{ict} + \sigma_{st} + \pi_c + \theta_h + \varepsilon_{ict},$$

where the dependent variable includes the level and proportion of foreign emissions by firm i in country c in year t. Our variable of interest is the difference between $SEER_{ht}$ and $SEER_{ct}$, the environmental policy scores for the home country (h) and the foreign country (c) in year t. The higher the value of $SEER_{ht} - SEER_{ct}$, the stronger the regulation at home is relative to the foreign country.

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

31 As a robustness test, we also re-estimate the regressions using the Poisson pseudo-maximum likelihood (PPML) estimation procedure instead of a Tobit model to deal with a lot of zero-emissions observations. The results are quantitatively similar.

and country-pair variables that reflect the following relations between the home and the foreign country: logged geographic distance (in kilometres), whether the countries share a common border, whether the countries share a colonial history and the logged trade volume between the two countries (in US$bn). We also include industry-year (σ_{st}), foreign-country (π_c) and home-country (θ_h) fixed effects.

In all regressions in Table 4, the coefficients for $SEER_{ht}-SEER_{ct}$ 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 with abroad is associated with up to an 84% increase in emissions in the respective foreign country.[32] This finding suggests that firms export pollution to countries where environmental regulation is relatively weaker. As the home and foreign country fixed effects capture the time-invariant unobservable factors of each country, the significance of the difference in SEER implies that allocation of polluting activities is a function of the differentials in the stringency of environmental policies between two countries. In other words, the results from the granular panel data at the firm–country–year level provide direct evidence of carbon leakage by multinational firms.

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 higher the percentage of production that occurs in foreign countries, the higher are a firm's foreign emissions. These results make intuitive sense considering that emissions are the direct result of a firm's production or operations.

4. ECONOMIC MECHANISM

In this section, we explore the economic mechanism for the relationship that we observe between CO_2 emissions and countries' environmental policies. We begin by examining whether pollution is pushed away by home environmental policies or is pulled abroad. Then, we explore the role of corporate governance. Finally, we assess the importance of pollution-intensive industries.

4.1. Pushed away by strict domestic policies or attracted by lenient foreign policies?

Our baseline results in Section 3 show that firms headquartered in countries with strict environmental policies reduce overall CO_2 emissions, but they shift polluting activities

32 From Column (1): $100 * (e^{0.40 * 1.52} - 1) = 83.7\%$.

Table 4. Analysis of firm–country-level emissions: effect of environmental policy gaps

	Scope 1 emissions		Scope 2 emissions	
Dependent variable:	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions
Specification:	Tobit (1)	Tobit (2)	Tobit (3)	Tobit (4)
$SEER_{ht}$−$SEER_{ct}$	0.40***	0.55***	0.47***	0.52***
	(2.93)	(3.02)	(3.78)	(3.22)
Firm characteristics				
ln(Assets)	2.39***	2.30***	1.97***	1.90***
	(32.68)	(16.93)	(30.92)	(14.36)
Foreign asset share	0.05***	0.07***	0.03***	0.05***
	(16.37)	(11.68)	(13.35)	(9.39)
Foreign country characteristics				
ln(GDP)	−0.42	−0.58	0.54	0.64
	(−1.14)	(−1.21)	(1.63)	(1.40)
Country pair characteristics				
ln(Geographic distance)	−1.69***	−2.18***	−1.33***	−1.84***
	(−5.55)	(−5.02)	(−5.01)	(−4.43)
Common border	0.81	2.19*	0.67	1.76
	(1.15)	(1.86)	(1.07)	(1.45)
Common colonial history	3.06***	4.46***	2.99***	4.50***
	(6.42)	(6.41)	(7.44)	(6.62)
ln(Trade)	1.93***	2.52***	1.86***	2.45***
	(10.00)	(8.51)	(10.71)	(8.94)
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
Foreign country	Yes	Yes	Yes	Yes
Home country	Yes	Yes	Yes	Yes
Pseudo *R*-squared	0.201	0.181	0.207	0.185
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

Notes: The table shows the effect of environmental regulation gaps between home and foreign countries on the firms' emissions in a specific country. We estimate Tobit regressions in which the dependent variable is ln(1 + Foreign emissions) in Columns (1) and (3) and Foreign emissions as a % of global emissions in Columns (2) and (4). Columns (1) and (2) show the results for Scope 1 emissions, and Columns (3) and (4) show the results for Scope 2 emissions. $SEER_{ht}$−$SEER_{ct}$ is our proxy for stringency and enforcement of environmental regulation in the home country (h) minus the foreign country (c), with higher values indicating stricter regulation at home. All regressions include industry–year, home country and foreign country fixed effects. Standard errors are clustered by country-pair. The definitions of all variables are provided in Appendix Table A1. 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.

to foreign countries, specifically those with relatively more lenient regulations than their home countries. In this section, we investigate the economic drivers of this finding. Specifically, we examine whether a push (stricter policies in home countries) or a pull (more lenient policies in foreign countries) is the main driver behind multinational firms' polluting behaviour.

Our main finding that multinationals tend to export pollution when environmental policies are strict in the home country can be explained by two non-mutually exclusive mechanisms. First, strict domestic policies can push away firms to pollute abroad. Facing tightened domestic policies, firms have a stronger incentive to export their polluting operations, because reducing emissions might be costly and can require investment in resources (the 'push' force). Second, countries with more lenient environmental policies may 'attract' pollution from firms headquartered in countries with relatively stricter environmental policies. In this case, even without any changes in domestic regulations, firms can be attracted by looser foreign policies and shift their polluting operations abroad (the 'pull' force).

Our firm–country–year panel dataset allows us to tease out these two forces. To assess whether multinational firms are pushed away from tighter policies in their home countries or are attracted by more lenient policies in foreign countries, we implement the following specifications:

$$y_{ict} = \gamma_1 \text{SEER}_{ht} + \gamma_2 \text{Controls}_{ict} + \sigma_{st} + \pi_{ct} + \theta_h + \varepsilon_{ict} (\text{A})$$

$$y_{ict} = \delta_1 \text{SEER}_{ct} + \delta_2 \text{Controls}_{ict} + \sigma_{st} + \pi_c + \theta_{ht} + \varepsilon_{ict} (\text{B}),$$

where the dependent variable is the level or the proportion of foreign emissions. In Equation (A), we include foreign country–year fixed effects (π_{ct}) to control for time-varying foreign country conditions. Thus, in this specification, we compare firms located in different home countries and examine whether they are polluting more *within* the same foreign country, depending on the strictness of environmental policies in their home country. If the stricter domestic policy drives firms to export pollution (the push hypothesis), holding fixed the foreign-country conditions, we expect that $\gamma_1 > 0$. In Equation (B), we examine the opposite force by including home country–year fixed effects (θ_{ht}). We examine the effect of the strictness of foreign environmental policy on attracting firms, comparing the behaviour of all multinational firms *within* the same home country–year. If the looser foreign regulations are the main driver of firms' foreign emissions (the pull hypothesis), we expect that $\delta_1 < 0$.

Table 5 reports the results. We find that in Panel A, the coefficients on SEER_{ht} are positive and significant, but in Panel B, those on SEER_{ct} are not statistically different from zero. The economic interpretation is that domestic countries that strengthen environmental policies push out multinational firms to emit CO_2 abroad. However, we find no evidence that countries that loosen environmental policies attract multinational firms to pollute in their countries. These findings highlight the importance of global regulatory coordination, given that many countries have been tightening domestic environmental policies. While our results in Table 4 generally support the pollution haven hypothesis, the findings in Table 5 suggest that firms are pushed abroad, as opposed to being pulled there.

Table 5. Home versus foreign environmental policies

Panel A: The push effect of $SEER_{home}$				
	Scope 1 emissions		Scope 2 emissions	
Dependent variable:	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions
	(1)	(2)	(3)	(4)
$SEER_{ht}$	1.03***	1.26***	1.48***	1.61***
	(4.61)	(4.22)	(7.42)	(5.54)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
Foreign country × Year	Yes	Yes	Yes	Yes
Home country	Yes	Yes	Yes	Yes
Pseudo R-squared	0.203	0.182	0.208	0.186
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
Panel B: The pull effect of $SEER_{foreign}$				
$SEER_{ct}$	−0.04	−0.13	0.16	0.18
	(−0.30)	(−0.65)	(1.22)	(1.02)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
Foreign country	Yes	Yes	Yes	Yes
Home country × Year	Yes	Yes	Yes	Yes
Pseudo R-squared	0.203	0.182	0.209	0.187
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

Notes: The table shows the effect of environmental regulations in home and foreign countries separately on the firms' emissions in a specific country, using a firm–country–year panel. We estimate Tobit regressions in which the dependent variable is ln(1 + Foreign emissions) in Columns (1) and (3) and Foreign emissions as a % of global emissions in Columns (2) and (4). Columns (1)–(2) and (3)–(4) show the results for Scope 1 and 2 emissions, respectively. Controls include ln(Assets), Foreign asset share, ln(Geographic distance), Common border, Common colonial history and ln(Trade). In Panel A, the main independent variable is $SEER_{ht}$, the environmental policy of the home country, and the regressions include industry–year, foreign country–year and home country fixed effects. In Panel B, the main independent variable is $SEER_{ct}$, the environmental policy of the foreign country, and the regressions include industry–year, foreign country and home country–year fixed effects. Standard errors are clustered by country-pair. Robust t-statistics are shown in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

4.2. 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, such interests have been confined to their financial interests; therefore, firms with good corporate governance are expected to minimize costs.[33] As such, if governance is related to the maximization of profits and complying with strict home environmental regulation is costly, we would expect firms with good corporate governance to be 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 *I*(Strong governance), a dummy variable indicating good corporate governance practices. *I*(Strong governance), based on the CGVSCORE from the Asset4 dataset, receives a value of 1 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. 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 6. 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 both Panels A and B 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 and Scope 2 emissions abroad (the interaction cancels out the main effect; see the *F*-test in Column (3)). Since well-governed firms thus reduce emissions at home while keeping foreign emissions unchanged, there is an overall higher percentage share of foreign emissions (the interaction adds to the main effect; see the *F*-test in Column (4)). Note that 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 an agenda of corporate social responsibility.

33 In recent years, a growing number of institutional investors are also interested in returns that go over and above financial 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 success of the company.

Table 6. Environmental policies and firms' corporate governance

Dependent variable:	ln(1 + Global emissions)	ln(1 + Home emissions)	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions
Specification:	OLS (1)	Tobit (2)	Tobit (3)	Tobit (4)
Panel A: Scope 1 emissions				
$SEER_{ht}$	−0.13*	−0.22*	0.41***	3.44**
	(−1.90)	(−1.95)	(2.88)	(2.51)
$SEER_{ht}\times I$(Strong governance)	−0.02	−0.77***	−0.29	5.42**
	(−0.12)	(−2.66)	(−1.43)	(2.19)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
F-test	1.42	11.55***	0.47	14.18***
Adjusted/pseudo *R*-squared	0.683	0.123	0.125	0.0616
Observations	4,376	4,376	4,376	4,376
of which censored at 0		196	406	406
of which censored at 100				196
Panel B: Scope 2 emissions				
$SEER_{ht}$	−0.16***	−0.36***	0.38***	6.41***
	(−2.92)	(−3.60)	(3.01)	(4.92)
$SEER_{ht}\times I$(Strong governance)	−0.07	−0.62*	−0.19	5.06*
	(−0.74)	(−1.95)	(−1.04)	(1.96)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
F-test	6.99***	10.17***	1.81	23.28***
Adjusted/pseudo *R*-squared	0.568	0.0910	0.117	0.0630
Observations	4,442	4,442	4,442	4,442
of which censored at 0		159	353	353
of which censored at 100				159

Notes: The table shows the role of firms' corporate governance in modulating the relationship between the domestic environmental policy and firms' emissions. Panels A and B show results for Scope 1 and 2 emissions, respectively. Results are estimated using OLS (Column (1)) and Tobit (Columns (2)–(4)) regressions with standard errors clustered by firm. Controls include ln(Assets), Foreign asset share, ln(GDP), GDP per capita growth and *I*(Strong governance). All regressions include industry–year fixed effects. 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 SEER×*I*(Strong governance). ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Our finding is consistent with recent papers documenting that firms' compliance with environmental standards is positively recognized by shareholders. For example, Dowell et al. (2000) find that firms that comply with strict environmental regulations by global 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.[34] Our result of the prudent polluting behaviours of well-governed firms raises the possibility that strong firm-level governance can mitigate negative externalities associated with strict national regulations.

4.3. Pollution-intensive industries

We next examine whether firms adjust their behaviour with respect to home-country environmental policy differently across industries. We are interested in the pollution-intensive industries that 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 define *I*(Pollution intensive) as a dummy for firms in industries with high pollution intensity. We base our indicator on the definition used by the European Union (EU), which measures the kilograms of CO_2 emitted in generating one euro of gross value added. The industry–year table provided by the EU is presented in Panel A of Appendix Table A3, 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 kg 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 kg of CO_2 per one euro of gross value added. All other industries emit less than 2 kg 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.

Panel B of Appendix Table A3 presents summary statistics for firms classified as being in pollution-intensive industries and the rest of firms.[35] Only 6.5% of all firm-years for which we have matched industry information are classified as pollution-intensive, yet the total 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%).[36]

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 7. Panel A focuses on Scope 1 emissions. The

34 Given this evidence that environmental policies can affect firm value, several recent studies have attempted to identify determinants of firms' polluting behaviours. For example, financial constraints are known to exacerbate firms' incentives to pollute (Levine et al., 2018; Bartram et al., 2019; Kim and Xu, 2020; Shive and Forster, 2020). Our paper adds to this strand of the literature by providing evidence on the importance of operating locations in understanding firms' polluting incentives.

35 We lose some firm–year observations in a subset of the sample that we cannot map into the NACE industry codes.

36 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.

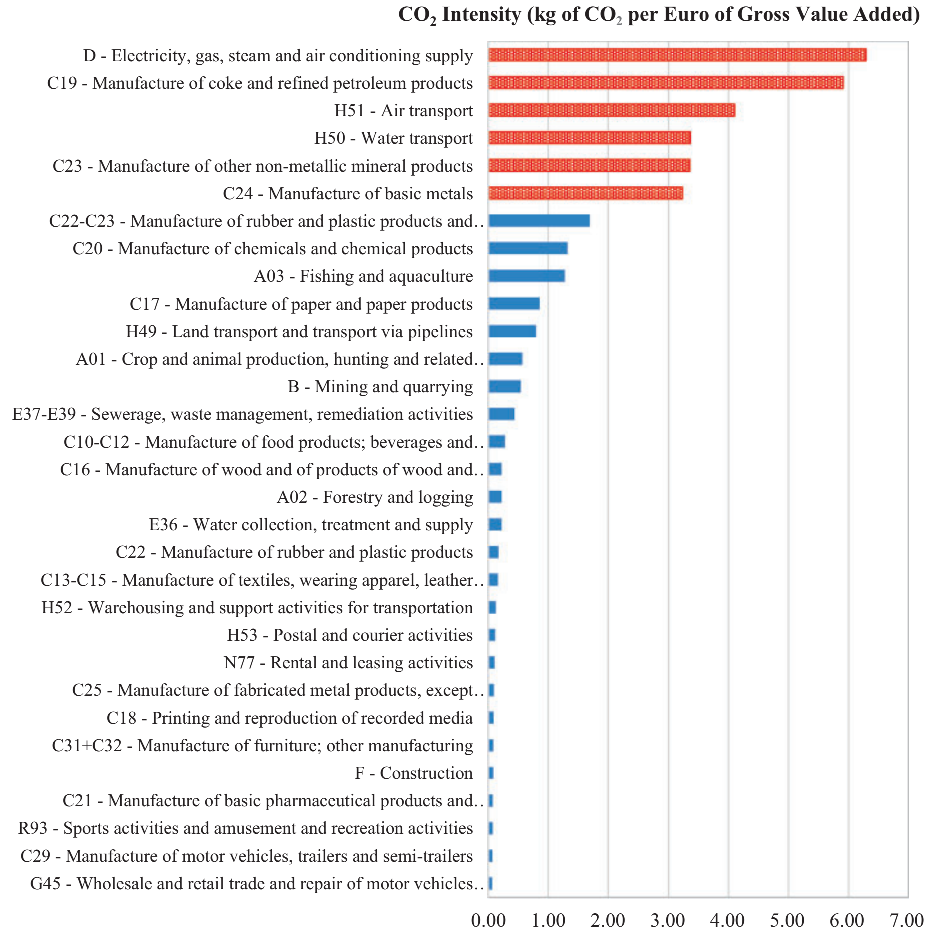


Figure 5. Pollution intensity by industry

Notes: This chart shows the CO_2 intensity of various industries in the EU (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.

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 domestic 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. While the results are similar, they are 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 twice the sensitivity to home environmental policies when it comes to polluting in foreign countries.

These results have important implications for policymakers because firms in pollution-intensive industries emit of the bulk of CO_2 worldwide. 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.

5. ROBUSTNESS TESTS

In this section, we further corroborate our findings by conducting robustness tests on the environmental policy measures and control variables and by addressing the concern of sample selection and self-reporting biases.

5.1. Stringency versus 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 A4, 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 up to a 30% decrease in emissions at home and up to a 37% increase in emissions abroad.[37] Similarly, a one-standard-deviation increase in EER (0.68) is associated with up to a 34% decrease in emissions at home and up to a 40% increase in emissions abroad.[38]

37 From Column (3) in Panel A: 100 * ($e^{-0.48 * 0.56}$ – 1) = –23.6%; from Column (3) in Panel B: 100 * ($e^{-0.66 * 0.56}$ – 1) = –30.9%; from Column (5) in Panel A: 100 * ($e^{0.47 * 0.56}$ – 1) = 30.1%; from Column (5) in Panel B: 100 * ($e^{0.57 * 0.56}$ – 1) = 37.6%.

38 From Column (4) in Panel A: 100 * ($e^{-0.47 * 0.68}$ – 1) = –27.4%; from Column (4) in Panel B: 100 * ($e^{-0.64 * 0.68}$ – 1) = –34.4%; from Column (6) in Panel A: 100 * ($e^{0.44 * 0.68}$ – 1) = 35.3%; from Column (6) in Panel B: 100 * ($e^{0.50 * 0.68}$ – 1) = 40.5%.

Table 7. Environmental policies and pollution-intensive industries

Dependent variable:	ln(1 + Global emissions)	ln(1 + Home emissions)	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions
Specification:	OLS (1)	Tobit (2)	Tobit (3)	Tobit (4)
Panel A: Scope 1 emissions				
$SEER_{ht}$	−0.20***	−0.39***	0.25**	3.76***
	(−3.23)	(−3.35)	(2.25)	(2.95)
$SEER_{ht} \times I$(Pollution intensive)	0.30***	0.29***	0.27**	−0.19
	(4.94)	(2.64)	(2.25)	(−0.15)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
F-test	1.66	0.33	10.78***	4.11**
Adjusted/pseudo R-squared	0.668	0.111	0.125	0.056
Observations	4,559	4,559	4,559	4,559
of which censored at 0		216	431	431
of which censored at 100				216
Panel B: Scope 2 emissions				
$SEER_{ht}$	−0.23***	−0.52***	0.31***	7.03***
	(−5.02)	(−5.09)	(3.17)	(5.94)
$SEER_{ht} \times I$(Pollution intensive)	0.13***	0.12	0.23**	0.26
	(2.60)	(1.45)	(2.34)	(0.25)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
F-test	2.39	8.96***	16.17***	22.09***
Adjusted/pseudo *R*-squared	0.590	0.093	0.115	0.057
Observations	4,724	4,724	4,724	4,724
of which censored at 0		184	380	380
of which censored at 100		0	0	184

Notes: The table shows the relationship between the domestic environmental policy and firms' emissions by industry. Panels A and B show results for Scope 1 and 2 emissions, respectively. Results are estimated from OLS (Column (1)) and Tobit (Columns (2)–(4)) regressions with standard errors clustered by firm. Controls include ln(Assets), Foreign asset share, ln(GDP) and GDP per capita growth. All regressions include industry–year fixed effects. 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 SEER×*I*(Pollution intensive). ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

In Panels C and D of Appendix Table A4, 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 show that 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 behaviour.

5.2. Addressing self-reporting bias and sample selection 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 possibility, 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. This analysis enables us 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 A5. The results are generally consistent with our main results in Table 3: SEER has a negative effect on global and home emissions levels and a positive relation with foreign emissions (both absolute and relative). This observation implies that among firms whose reported emissions are externally verified, stricter environmental regulations in the home market are associated with lower emissions at home but 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 up to a 31% smaller share of home emissions[39] and up to a 32% greater share of foreign emissions.[40]

One might also be concerned that our results are driven by the composition of firms that report CO_2 emissions during the sample period because the number of firms responding to the CDP survey increased over time. To address this selection bias, we perform a robustness test using a subset of 621 firms that answered the CDP survey in 2008, the beginning year of our sample period, holding the composition of firms constant. The results are reported in Appendix Table A6. We find that the results of the effect of SEER on global, home and foreign emissions using the subsample are robust and quantitatively similar to the baseline results in Table 3.

5.3. Controlling for comparative advantage

In Tables 3 and 4, we control for country, industry and firm characteristics, including the firm's foreign asset share as a broad proxy for the firms' foreign operations. Nevertheless, we might be missing a major consideration in the firm's strategic decision

39 From Column (2) in Panel A: $100 * (e^{-0.38 * 0.9} - 1) = -29.0\%$; from Column (2) in Panel B: $100 * (e^{-0.42 * 0.9} - 1) = -31.5\%$.

40 From Column (3) in Panel A: $100 * (e^{0.26 * 0.9} - 1) = 26.4\%$; from Column (3) in Panel B: $100 * (e^{0.31 * 0.9} - 1) = 32.2\%$.

to operate—and thus consequently to pollute—abroad or at home: the comparative advantage a firm has when operating in different countries. If comparative advantage in pollution is correlated with the classical advantages in factors of production such as skilled labour and capital, then our SEER coefficients might incorrectly reflect this classic comparative advantage.

To isolate the sheer comparative advantage in CO_2 emissions, we additionally control for the classic comparative advantage variables following Romalis (2004) and Nunn (2007).[41] Doing so reduces the sample size substantially because skilled labour and capital endowment data are not available for all countries in our sample, and factor intensities are only available for manufacturing industries.

Results are reported in Appendix Tables A7 and A8 for firm-year level and firm–country–year level emissions, respectively. In general, our results are robust to the inclusion of comparative advantage control variables. However, in Appendix Table A7 not all coefficients of $SEER_{home}$ are significant. To determine whether this reduced significance is due to the inclusion of the comparative advantage controls or the reduced sample size, we re-estimate Appendix Table A7 for the same, smaller samples but without including the comparative advantage controls. We again find some insignificant coefficients for $SEER_{home}$, indicating that the reduced sample size is responsible for the loss in significance and not the addition of the comparative advantage variables.[42]

6. CONCLUSION

Pollution and the emission of greenhouse gases is an undesired externality of economic activity that contributes significantly to the changing climate around the world. This externality is costly to avoid. As a result, firms are likely to find ways to circumvent costly CO_2 pollution abatement requirements. One strategy for firms operating in multiple locations could be to transfer operating 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 known as carbon leakage.

Our study sheds light on this argument using a novel dataset comprising firm-level CO_2 emissions data. We find a strong pattern that firms 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 emissions levels are significantly higher abroad when 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. More specifically, we find that firms emit less at home when headquartered in countries with stricter regulations. These firms, however, pollute more abroad, typically in countries with weaker regulations.

41 We thank the reviewer for pointing this out to us.

42 The results are available upon request.

The combination of push and pull factors can explain our main finding that firms perform their production activities in countries with looser environmental regulation relative to their home country. Our results suggest that tightening environmental policies in home countries, not the laxer policies in foreign countries, incentivize multinational firms to shift polluting activities abroad. This result underscores the possibility that, without global coordination, strengthening domestic environmental policies could create an unintended negative externality, pushing firms to pollute elsewhere.

On the positive side, the higher foreign emissions levels do not completely outweigh the reduction at home. Thus, individual countries can make a difference. However, our findings overall highlight the need for collective action to bring down global emissions levels further. The 2015 Paris Agreement on climate change was an important step towards 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. Our results further suggest that policymakers might be most effective if they focus on curbing the ability of pollution-intensive industries to export pollution to countries with laxer environmental regulations.

For multinational firms with production facilities around the globe, our results imply that—depending on how quickly and effectively countries implement the Paris Agreement and the European Green Deal—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 these international agreements will harmonize national environmental regulation enough 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.

Discussion

Dennis Novy

University of Warwick

Citizens of rich countries and increasingly those of emerging economies generate an unsustainable amount of CO_2 emissions, not least when they consume products that were produced and delivered with a heavy carbon footprint. A large fraction of these emissions tends to be mediated by multinational firms due to their sheer size, just as multinationals are associated with a large share of economic activity in general. For example, we know from the international trade literature that multinational firms dominate foreign transactions, many of which are within the firm. In principle it should therefore not be surprising that multinationals have a big carbon footprint. But perhaps the size of the footprint is larger than many would expect. As López et al. (2019) show, if CO_2

emissions of US multinationals outside the US were catalogued as a country, they would rank as the 12th top emitter in the world (when emissions are measured in terms of CO_2 units). By comparison this would make US multinationals foreign operations a larger CO_2 emitter than the entire UK economy or the entire Australian economy. This is remarkable and deserves close attention.

This paper tackles the important and timely question of multinational firms' CO2 emissions. The authors use panel data for close to 2000 public firms and their CO2 emissions across 218 countries based on annual survey data over the period from 2008 to 2015. The novel aspect is that the authors observe emissions of each firm separately by country. This allows them to study pollution substitution across space ("carbon leakage"). They find that polluting activities are shifted to countries with weaker environmental policies. The effects are economically large: "A one-standard-deviation increase in the strictness of environmental policies in the home country is associated with a 29% reduction of CO2 emissions at home, but it is also associated with up to a 43% increase in emissions abroad." They find evidence of less pollution in the aggregate with about 14% lower CO2 emissions at the global level.

Overall, the results are consistent with the pollution haven hypothesis. Pollution substitution seems mainly driven by push forces (through tough policies at home) rather than pull forces (through lenient policies abroad). The authors identify an important mechanism in that strong firm-level governance can mitigate the negative externalities of stricter regulation. That is, good governance is associated with less pollution being pushed to more lenient jurisdictions. The paper thus highlights a clear need for global policy coordination and makes an important and policy-relevant contribution.

Some caveats should apply to the interpretation of the empirical results. The survey reached out to about 3000 firms at the beginning of the sample and 6000 towards the end, and the authors use data for around 2000 firms. The authors address this potential sample selection problem by checking the subsample of firms which appeared in 2008 already, and the overall results are similar. This is reassuring but as the authors point out, the firms which report CO2 emissions are larger in terms of assets and market capitalization compared to the universe of multinational firms. They also have higher institutional ownership, which could imply more pressure to release information related to corporate social responsibility. It is likely that firms which do not report CO_2 emissions behave differently.

Another caveat is that the results should be interpreted as correlations. It might be tempting to see the "push" and "pull" of pollution substitution as a causal relationship, but this interpretation would be misguided. For instance, environmental regulation is likely endogenous in many industries. Of course, this is a standard caveat and it should not take away from the paper's insights, but it is an important qualification to keep in mind.

It might be instructive to look at the paper from a theoretical perspective. First, given the rise of global value chains one aspect is the upstream-downstream structure of production. As Copeland, Shapiro and Taylor (2021) point out, dirty industries tend to be more upstream. How does upstream regulation affect downstream pollution, and vice versa? Regulation can induce either positive or negative pollution spillovers along the supply chain. It would be particularly interesting to examine indirect emissions from suppliers and buyers both within and outside the firm, but data on indirect emissions (Scope 3 emissions) are limited and only available at the global level. This remains as an important task for future research. Second, should we worry about general equilibrium effects? For example, if all countries increase their standards or if standards converge, what happens in the aggregate? This is beyond the scope of the current paper but it is a related question.

In terms of the mechanism of pollution substitution, the paper considers the intensive margin of pollution for a given set of plant locations. How about the extensive margin when firms choose to become multinationals or open up new foreign subsidiaries in order to shift pollution abroad? This becomes an issue of endogenous location choice even when the headquarters may remain in a country with high environmental standards. Also, if policies are toughened, do firms invest in more environmentally friendly products and more advanced production technologies? These issues likely require micro data and are beyond the scope of the paper. But the authors estimate the effect of environmental policies on pollution "efficiency" measured as the amount of CO2 emissions relative to the value of assets in a particular location. They find evidence that tough domestic regulation is associated with better pollution efficiency at home and worse pollution efficiency abroad.

Finally, it would be interesting to put the emissions of multinational firms into the bigger context. How important are multinationals compared to other sources of CO_2 emissions, and has their role grown or shrunk in recent years? What about other greenhouse gases apart from CO_2? Copeland, Shapiro and Taylor (2021) show that different types of pollution are correlated, in particular CO_2 and NOx emissions. The insights on CO_2 emissions therefore arguably carry over to other settings, at least roughly. This more general framing would be useful for policymakers to identify the areas where policies could potentially make the biggest difference in terms of reducing emissions. Overall, this is a timely paper with great new data and important insights.

Eleonora Patacchini

Cornell University

Statements on climate changes from several scientific organizations show that global climate has warmed in response to increasing concentrations of carbon dioxide (CO_2) and that human activities are the dominant cause of the rapid warming (IPCC, 2013). There is an almost unanimous consensus that stricter environmental regulation and enforcement are desirable. Core policy questions are: what would be the consequences of a tightening in environmental policies? Shall we expect significant pollution shifting from countries with stricter regulations to countries with more lenient policies? And, who can bear the short-run costs of pro-environmental interventions and how?

This paper provides novel and insightful evidence to this debate by examining the impact of environmental policies on multinational firms polluting activities both at home and in foreign countries. The analysis is based on self-reported information from a survey of the largest firms in the world (1,970 large firms headquartered in 48 countries) during the 20082015 period. The data are provided by the CDP (formerly known as the Carbon Disclosure Project). Importantly, the questionnaire asks about the CO2 emissions of each multinational firm in each country and the perception of the stringency of their country s environmental regulation. This data is merged with firm-specific financial information, including measures of the corporate governance quality of firms.

The main findings are very interesting. Firms headquartered in countries with stricter regulations emit less domestically and export more pollution abroad. This pattern seems related to stricter domestic policies inducing firms to export pollution rather than to more lenient foreign policies attracting firms producing pollution. Corporate governance plays an important role: firms with a higher quality of governance systems are the ones that produce lower pollution domestically and do not emit more abroad.

There are three caveats. First, the results are obtained using OLS regressions and it is hard to assess causality. Because of the endogeneity issues that are endemic to the analysis of any policy effect, one cannot exclude the presence of troubling omitted variables or reverse causality issues. For example, cultural attitudes may cause both (strict) environmental regulations and (less) production of pollution at home, or countries may promote weak regulations to attract polluting firms. Second, the information is self-reported. It is thus possible that pro-environment leaders may overstate the strictness of environmental policy to highlight their own country's environmental attitude, and pro-environment firms may understate their C02 emission to please the government. Third, there may be self-selection of firms into the survey since participation is voluntary. In addition, the survey is only sent to the largest firms in the world. An alternative story could be that firms in countries with stricter regulation do not emit less but simply outsource pollution to many small firms that are not in the sample. Nevertheless, the evidence in the paper is of great value. We know very little about the public and private response to the threats of climate change. As mentioned before, environmental regulations typically come with a trade-off between short-run costs and long-run gains.

This paper highlights the importance of corporate governance and of the quality of managers to make progress in this direction. This is a novel and extremely interesting finding. Future research should further investigate whether better managers are simply more able to outsource polluting activities both domestically and abroad or if they are promoting important investments with long-run returns.

Panel discussion

The first comment from the audience was from Sebastian Axbard. He asked whether it is possible to exploit the regulatory data, and in particular the timing of regulation, to try to achieve some causal identification.

Yeejin Jang replied, arguing that the authors were already working on the challenge to identify a causal relationship in the data, in particular by means of a difference-in-differences approach or an event study setting exploiting the different timing with which countries adopted the Paris agreement. Responding to the discussants, she also explained that it is possible to shed some more light on the intensive vs extensive margin channel, by looking at firm-level data. Similarly, she added that it is also possible to devote some additional analysis to the role of managers. As for the composition of the firms in the sample, she agreed that this is not consistent over time in the data and it would hence be important to think more at the composition effect, although the authors already performed a variety of robustness checks in their analysis.

Alessandra Bonfiglioli asked about the characteristics of the multinationals analysed in the sample. In particular, she asked whether the majority of firms is horizontal or vertical, that is multinationals that purposely outshore polluting activities abroad, or multinationals producing polluting products in a foreign country that happens to have more lenient environmental policies. Moreover, she suggested that the authors should consider using a specification where the stringency of environmental policy in the foreign country is interacted with the emission intensity of the industry, in order to control for possible comparative advantages.

In response, Yeejin Jang argued that how multinationals in the sample operate varies a lot and that the authors do not have detailed firm-level data regarding the vertical vs horizontal aspect. She also agreed that it would be interesting to try to further analyse the role of comparative advantage and added that the authors already performed some robustness checks controlling for a country s comparative advantage in labour or capital in different industries.

Itzhak Ben-David also agreed that looking at comparative advantage may be very important and that the authors could focus on this by using industry-level data, for example by looking at the relative size of different industries in different countries.

APPENDIX

Table A1. Variable definitions and sources

Variable	Description	Units	Data source
Panel A: Variables used in firm-level analyses			
Dependent variables			
Global emissions	Firm *i*'s CO_2 emissions globally in year *t*, calculated for either Scope 1, Scope 2 or Scope 3 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 as a % of global emissions	Firm *i*'s CO_2 emissions in all foreign countries combined in year *t* as a percentage of firm *i*'s global CO_2 emissions in year *t*, calculated for either Scope 1 or Scope 2 emissions	0–100%	CDP
Independent variables			
SER	Stringency of environmental regulation in firm *i*'s home country in year *t*	1–7	WEF
EER	Enforcement of environmental regulation in firm *i*'s home country in year *t*	1–7	WEF
SEER	Stringency and enforcement of environmental regulation in firm *i*'s home country in year *t*; calculated as SEER = (SER * EER)/7	0.14–7	WEF
Assets	Total assets of firm *i* in year *t* (WC02999)	US$ mil	Worldscope
Foreign asset share	Firm *i*'s foreign assets as a percentage of total assets in year *t* (WC08736)	0–100%	Worldscope
I(Strong governance)	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
I(Pollution intensive)	Dummy equal to 1 if firm *i* belongs to a pollution-intensive industry, 0 otherwise; industries with NACE Industry 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
GDP	GDP of firm *i*'s home country in year *t*	Current US$ mil	World Bank's World Development Indicators
GDP per capita growth	Annual percentage growth rate of GDP per capita of firm *i*'s home country in year *t*	0–100%	World Bank's World Development Indicators
CA (Skill)	The comparative advantage in skilled labour ($h_s H_c$), where h_s denotes the skill intensity of production in the firm's industry *s* and H_c denotes endowment in skilled labour in country (*c*). Skill intensity h_s is the ratio of non-production		NBER-CES Manufacturing Industry Database

(*continued*)

Table A1. Continued

Variable	Description	Units	Data source
	worker wages to total wages in industry *s* in the United States, averaged across the period 2008–11. Industries are identified based on SIC codes. A country's skilled labour endowment H_c is measured as the natural log of the ratio of the population aged 25 years or above that completed secondary education to those that did not complete secondary education. Data for factor intensity h_s are obtained from the NBER-CES Manufacturing Industry Database, which contains annual data up to 2011. Data for skilled labour endowment H_c are obtained from the Barro–Lee Educational Attainment Dataset.		(http://data.nber.org/nberces), Barro–Lee Educational Attainment Dataset (http://barrolee.com)
CA (Capital)	The comparative advantage in capital (k_sK_c), where k_s denotes the capital intensity of production in the firm's industry *s* and K_c denotes endowment in capital in country *c*. Capital intensity k_s is the real capital stock in industry *i* divided by the value added in industry *i* in the United States averaged across the period 2008–11. Industries are identified based on SIC codes. A country's capital endowment K_c is the natural log of the capital stock per worker averaged across the period 2008–15. Data for factor intensity k_s are obtained from the NBER-CES Manufacturing Industry Database, which contains annual data up to 2011. Data for capital endowment K_c are obtained from the Penn World Tables.		NBER-CES Manufacturing Industry Database (http://data.nber.org/nberces), Penn World Tables (https://www.rug.nl/ggdc/productivity/pwt)
Panel B: Variables used in firm-country-level analyses			
Dependent variables			
Foreign emissions	Firm *i*'s CO_2 emissions in foreign country *c* in year *t*, calculated for either Scope 1 or Scope 2 emissions	tons	CDP
Foreign emissions as a % of global emissions	Firm *i*'s CO_2 emissions in foreign country *c* in year *t* as a percentage of firm *i*'s global CO_2 emissions in year *t*, calculated for either Scope 1 or Scope 2 emissions	0–100%	CDP
Independent variables			
$SEER_{ht}$–$SEER_{ct}$	Difference between stringency and enforcement of environmental regulation in firm *i*'s home country (h) and foreign country (c) in year *t*; each country's SEER is calculated as SEER = (SER * EER)/7	−7 to +7	WEF
Assets	Total assets of firm *i* in year *t* (WC02999)	US$ mil	Worldscope
Foreign asset share	Firm *i*'s foreign assets as a percentage of total assets in year *t* (WC08736)	0–100%	Worldscope
GDP	GDP in foreign country *c* in year *t*	Current US$ mil	World Bank's World Development Indicators

(*continued*)

Table A1. Continued

Variable	Description	Units	Data source
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) and 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 the same country, 0 otherwise	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			
Year	Dummies identifying the year *t* in which firm *i* emits CO_2, 2008–15	0/1	CDP
Industry	Dummies based on two-digit SIC codes (WC07021)	0/1	Worldscope
Home country	Dummies identifying the home country *h* in which firm *i* is headquartered	0/1	CDP
Foreign country	Dummies identifying the foreign country *c* in which firm *i* emits CO_2	0/1	CDP

Table A2. Emission efficiency: scaling by home and foreign assets

Panel A: Summary statistics

	N	Mean	Std Dev	Min	Median	Max
Scope 1 CO_2 emissions						
Home emissions/Home assets	4,812	7.88	22.22	0.00	0.60	202.33
Foreign emissions/Foreign assets	4,660	10.85	30.00	0.00	1.34	322.91
Scope 2 CO_2 emissions						
Home emissions/Home assets	4,910	2.93	5.91	0.00	0.84	56.99
Foreign emissions/Foreign assets	4,752	8.31	13.59	0.00	2.42	94.65

Panel B: Analysis of firm-level emissions

	Scope 1 emissions		Scope 2 emissions	
Dependent variable:	Home emissions/ home assets	Foreign emissions/ foreign assets	Home emissions/ home assets	Foreign emissions/ foreign assets
Specification:	Tobit	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)
SEER	−1.88***	2.18**	−1.24***	1.50***
	(−2.71)	(2.13)	(−5.40)	(3.98)
Firm characteristics				
ln(Assets)	0.10	2.33***	−0.28***	0.68*
	(0.24)	(3.44)	(−2.77)	(1.94)
Home country characteristics				
ln(GDP)	0.77*	−0.72	−0.06	0.40
	(1.65)	(−1.04)	(−0.43)	(1.12)
GDP per capita growth	0.65**	−0.19	−0.06	−0.20
	(2.24)	(−0.60)	(−1.00)	(−1.36)
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
Pseudo *R*-squared	0.0461	0.0416	0.0413	0.0536
Observations	4,812	4,660	4,910	4,752
of which censored at 0	203	719	186	693

Notes: The table presents results on the effect of home-country environmental policies on home and foreign CO_2 emissions, scaled by assets. Panel A shows the summary statistics for the Scopes 1 and 2 emissions in tons in home and foreign countries, scaled by home and foreign assets in US dollars, respectively. Emissions variables are multiplied by 100 and are trimmed at 1% and 99%. Panel B shows the estimates from Tobit regressions in which the dependent variables are home emissions divided by domestic assets in Columns (1) and (3) and foreign emissions divided by foreign assets in Columns (2) and (4). Emissions are based on Scope 1 in Columns (1) and (2) and on Scope 2 in Columns (3) and (4). SEER is our proxy for stringency and enforcement of environmental regulation in the firm's home country, with higher values indicating stricter regulation. 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.

Table A3. Pollution-intensive industries

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

(continued)

Table A3. Continued

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
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 and 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
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 broadcasting activities	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

(*continued*)

Table A3. Continued

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
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

Table A3. Continued

Panel B: Summary statistics: pollution-intensive versus non-pollution-intensive industries

	Pollution-intensive industry				Non-pollution-intensive industry			
	N	Mean	Sth Dev	Median	*N*	Mean	Sth 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

Notes: 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 EU (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 are set in 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.

Table A4. SER versus EER

Dependent variable:	ln(1 + Global emissions)		ln(1 + Home emissions)		ln(1 + Foreign emissions)		Foreign emissions as a % of global emissions	
Specification:	OLS (1)	OLS (2)	Tobit (3)	Tobit (4)	Tobit (5)	Tobit (6)	Tobit (7)	Tobit (8)
Panel A: Scope 1 emissions								
SER (stringency)	−0.25***		−0.48***		0.47***		5.09***	
	(−2.62)		(−2.70)		(2.60)		(2.66)	
EER (enforcement)		−0.19**		−0.47***		0.44***		5.41***
		(−2.47)		(−3.43)		(2.99)		(3.49)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects								
Industry × Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted/Pseudo R-squared	0.684	0.684	0.120	0.121	0.122	0.122	0.0569	0.0574
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

(continued)

Table A4. Continued

Dependent variable:	ln(1 + Global emissions)		ln(1 + Home emissions)		ln(1 + Foreign emissions)		Foreign emissions as a % of global emissions	
Specification:	OLS (1)	OLS (2)	Tobit (3)	Tobit (4)	Tobit (5)	Tobit (6)	Tobit (7)	Tobit (8)
Panel B: Scope 2 emissions								
SER (stringency)	−0.31***		−0.66***		0.57***		10.38***	
	(−4.36)		(−4.07)		(3.55)		(5.76)	
EER (enforcement)		−0.24***		−0.64***		0.50***		9.84***
		(−3.92)		(−4.88)		(3.88)		(6.58)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects								
Industry × Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted/pseudo R-squared	0.583	0.582	0.0901	0.0912	0.116	0.116	0.0587	0.0597
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

Table A4. Continued

Dependent variable:	ln(1 + Global emissions)	ln(1 + Home emissions)	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions
Specification:	OLS (1)	Tobit (2)	Tobit (3)	Tobit (4)
Panel C: Ortdogonalized environmental enforcement; Scope 1 emissions				
SER (stringency)	−0.14***	−0.27***	0.26***	2.84***
	(−2.61)	(−2.75)	(2.59)	(2.68)
EER_O (enforcement; orthogonalized)	0.01	−0.22**	0.19**	3.44***
	(0.21)	(−2.27)	(1.99)	(3.77)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
Adjusted/pseudo R-squared	0.684	0.121	0.122	0.0578
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: Ortdogonalized environmental enforcement; Scope 2 emissions				
SER (stringency)	−0.17***	−0.36***	0.32***	5.72***
	(−4.36)	(−4.13)	(3.54)	(5.84)
EER_O (enforcement; orthogonalized)	0.00	−0.28***	0.12	4.09***
	(0.08)	(−2.64)	(1.53)	(4.18)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
Adjusted/pseudo R-squared	0.583	0.0916	0.116	0.0600
Observations	5,018	5,018	5,018	5,018
of which censored at 0		196	430	430
of which censored at 100				196

Notes: 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 OLS and Columns (3)–(8) are estimated as Tobit models. All regressions include ln(Assets), Foreign asset share, ln(GDP), GDP per capita growth and industry-year 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.

Table A5. Subsample analysis: only externally audited emissions data

Dependent variable:	ln(1 + Global emissions)	ln(1 + Home emissions)	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions
Specification:	OLS (1)	Tobit (2)	Tobit (3)	Tobit (4)
Panel A: Scope 1 emissions				
$SEER_{ht}$	−0.16**	−0.38***	0.26**	3.08**
	(−2.32)	(−3.25)	(2.23)	(2.42)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes−	Yes
Adjusted/pseudo R-squared	0.723	0.137	0.142	0.0614
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				
$SEER_{ht}$	−0.15***	−0.42***	0.31***	6.07***
	(−3.03)	(−3.61)	(2.94)	(4.84)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
Adjusted/pseudo R-squared	0.608	0.0852	0.137	0.0653
Observations	2,895	2,895	2,895	2,895
of which censored at 0		115	168	168
of which censored at 100				115

Notes: The table presents evidence about the relation between emissions in foreign countries and home-country environmental policies for firms whose emissions information is externally verified. Panels A and B show results for Scope 1 and 2 emissions, respectively. Column (1) is estimated with OLS and Columns (2)–(4) are estimated as Tobit models. SEER is our proxy for stringency and enforcement of environmental regulation in the firm's home country, with higher values indicating stricter regulation. All regressions include ln(Assets), Foreign asset share, ln(GDP), GDP per capita growth and industry–year 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.

Table A6. Subsample analysis: firms that existed in 2008

Dependent variable:	ln(1 + Global emissions)	ln(1 + Home emissions)	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions
Specification:	OLS (1)	Tobit (2)	Tobit (3)	Tobit (4)
Panel A: Scope 1 emissions				
$SEER_{ht}$	−0.23**	−0.41***	0.48**	5.88***
	(−2.41)	(−2.61)	(2.55)	(3.01)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
Adjusted/pseudo R-squared	0.726	0.130	0.125	0.0430
Observations	2,947	2,947	2,947	2,947
of which censored at 0		88	364	364
of which censored at 100				88
Panel B: Scope 2 emissions				
$SEER_{ht}$	−0.29***	−0.59***	0.42**	9.73***
	(−3.84)	(−4.34)	(2.44)	(5.17)
Controls	Yes	Yes	Yes	Yes
Fixed effects				
Industry × Year	Yes	Yes	Yes	Yes
Adjusted/pseudo R-squared	0.586	0.104	0.121	0.0499
Observations	2,904	2,904	2,904	2,904
of which censored at 0		55	337	337
of which censored at 100				56

Notes: The table presents the robustness results on the relation between emissions in home and foreign countries and home-country environmental policies using a subsample of 621 firms that reported emissions data in 2008. Panels A and B show results for Scope 1 and 2 emissions, respectively. Column (1) is estimated with OLS, and Columns (2)–(4) are estimated as Tobit models. SEER is our proxy for stringency and enforcement of environmental regulation in the firm's home country, with higher values indicating stricter regulation. All regressions include ln(Assets), ln(GDP), GDP per capita growth and industry–year 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.

Table A7. Firm-level emissions: controlling for comparative advantage

Dependent variable:	ln(1 + Global emissions)		ln(1 + Home emissions)		ln(1 + Foreign emissions)		Foreign emissions as a % of global emissions	
Specification:	OLS (1)	OLS (2)	Tobit (3)	Tobit (4)	Tobit (5)	Tobit (6)	Tobit (7)	Tobit (8)
Panel A: Scope 1 emissions								
$SEER_{ht}$	−0.13*	−0.08	−0.26**	−0.17	0.38***	0.28**	3.59**	2.27
	(−1.72)	(−1.04)	(−2.14)	(−1.22)	(2.90)	(2.00)	(2.47)	(1.51)
Firm characteristics								
ln(Assets)	1.15***	1.14***	0.96***	0.99***	1.51***	1.44***	3.12***	1.77*
	(21.99)	(22.39)	(10.28)	(10.22)	(17.36)	(17.23)	(2.91)	(1.74)
Foreign asset share		0.00*		−0.02***		0.03***		0.48***
		(1.66)		(−2.69)		(6.12)		(8.53)
Home country characteristics								
ln(GDP)	0.16**	0.16**	0.92***	0.88***	−0.41***	−0.21*	−12.79***	−10.54***
	(2.43)	(2.30)	(7.38)	(6.34)	(−3.57)	(−1.82)	(−9.70)	(−7.51)
GDP per capita growth	0.00	−0.00	0.00	−0.00	−0.19***	−0.14***	−1.70***	−1.30***
	(0.23)	(−0.14)	(0.09)	(−0.10)	(−3.58)	(−2.84)	(−3.34)	(−2.72)
CA(Skill)	−0.93***	−0.85***	−1.72***	−1.76***	0.31	0.13	14.79***	14.77***
	(−5.20)	(−4.37)	(−7.24)	(−6.64)	(0.90)	(0.39)	(4.57)	(4.57)
CA(Capital)	0.01	0.01	0.01	−0.00	0.03	0.01	0.21	0.20
	(1.35)	(0.72)	(0.45)	(−0.22)	(1.62)	(0.96)	(1.25)	(1.18)
Fixed effects								
Industry × Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted/pseudo R-squared	0.630	0.625	0.107	0.110	0.0858	0.105	0.0295	0.0428
Observations	2,939	2,344	2,939	2,344	2,939	2,344	2,939	2,344
of which censored at 0			105	91	200	127	200	127
of which censored at 100							105	91

(*continued*)

Table A7. Continued

Dependent variable:	ln(1 + Global emissions)		ln(1 + Home emissions)		ln(1 + Foreign emissions)		Foreign emissions as a % of global emissions	
Specification:	OLS (1)	OLS (2)	Tobit (3)	Tobit (4)	Tobit (5)	Tobit (6)	Tobit (7)	Tobit (8)
Panel B: Scope 2 emissions								
$SEER_{ht}$	−0.17**	−0.12	−0.33***	−0.24*	0.39***	0.31**	4.13***	2.93*
	(−2.25)	(−1.47)	(−2.68)	(−1.79)	(2.95)	(2.10)	(2.81)	(1.91)
Firm characteristics								
ln(Assets)	1.14***	1.15***	0.94***	0.99***	1.52***	1.46***	3.38***	1.96*
	(21.87)	(22.11)	(9.82)	(9.87)	(16.95)	(16.71)	(3.06)	(1.87)
Foreign asset share		0.00		−0.02**		0.03***		0.49***
		(1.21)		(-2.56)		(5.67)		(8.46)
Home country characteristics								
ln (GDP)	0.15**	0.15**	0.92***	0.89***	−0.41***	−0.23*	−13.06***	−10.92***
	(2.18)	(2.00)	(7.34)	(6.41)	(−3.45)	(−1.86)	(−9.84)	(−7.77)
GDP per capita growth	0.00	−0.01	−0.01	−0.02	−0.20***	−0.15***	−1.72***	−1.26***
	(0.03)	(−0.37)	(−0.12)	(−0.33)	(−3.75)	(−2.87)	(−3.23)	(−2.59)
CA (Skill)	−0.88***	−0.79***	−1.72***	−1.77***	0.33	0.23	15.37***	15.97***
	(−4.78)	(−3.92)	(−7.07)	(−6.52)	(0.97)	(0.65)	(4.76)	(5.02)
CA (Capital)	0.01	0.01	0.00	−0.01	0.03*	0.02	0.26	0.27
	(1.20)	(0.63)	(0.21)	(−0.51)	(1.90)	(1.29)	(1.58)	(1.58)
Fixed effects								
Industry × Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted/pseudo *R*-squared	0.626	0.623	0.108	0.113	0.0867	0.103	0.0308	0.0449
Observations	2,752	2,185	2,752	2,185	2,752	2,185	2,752	2,185
of which censored at 0			95	83	189	122	189	122
of which censored at 100							95	83

Notes: This table replicates Table 3 and adds control variables for the comparative advantage of the home country. Panels A and B show results for Scope 1 and 2 emissions, respectively. Columns (1) and (2) are estimated with OLS, and Columns (3)–(8) are estimated as Tobit models. SEER is our proxy for stringency and enforcement of environmental regulation in the firm's home country, with higher values indicating stricter regulation. CA(Skill) and CA(Capital) are our additional controls for comparative advantage in skilled labour and capital of the firm's industry in the home country, respectively. All regressions include industry–year 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.

Table A8. Firm–country-level emissions: controlling for comparative advantage

	Scope 1 emissions		Scope 2 emissions	
Dependent variable:	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions	ln(1 + Foreign emissions)	Foreign emissions as a % of global emissions
Specification:	Tobit (1)	Tobit (2)	Tobit (3)	Tobit (4)
$SEER_{ht}-SEER_{ct}$	0.88***	0.92***	0.99***	0.94***
	(5.24)	(4.77)	(6.41)	(5.30)
Firm characteristics				
ln(Assets)	2.39***	1.81***	2.00***	1.58***
	(30.87)	(16.06)	(28.12)	(14.37)
Foreign asset share	0.04***	0.04***	0.03***	0.04***
	(10.52)	(8.90)	(9.68)	(7.65)
Foreign country characteristics				
ln(GDP)	0.55	0.92**	0.94**	1.58***
	(1.41)	(2.05)	(2.40)	(3.12)
CA (Skill)	1.49***	2.23***	1.24**	1.47*
	(2.90)	(2.93)	(2.37)	(1.78)
CA (Capital)	−0.24	−0.36**	−0.21	−0.38**
	(−1.47)	(−1.99)	(−1.56)	(−2.47)
Home country characteristics				
CA (Skill)	−2.03***	−1.69***	−1.23***	−0.72
	(−4.62)	(−3.29)	(−2.71)	(−1.39)
CA (Capital)	0.19	0.31*	0.23*	0.39***
	(1.25)	(1.81)	(1.74)	(2.64)
Country pair characteristics				
ln(Geographic distance)	−1.25***	−1.38***	−1.25***	−1.52***
	(−3.83)	(−3.38)	(−4.01)	(−3.40)
Common border	−0.16	1.00	−0.77	0.21
	(−0.22)	(1.06)	(−1.14)	(0.21)
Common colonial history	1.91***	2.87***	1.74***	3.14***
	(3.76)	(3.17)	(3.97)	(2.88)
ln(Trade)	1.65***	1.73***	1.68***	1.80***
	(7.95)	(7.01)	(8.11)	(6.85)
Fixed effects				
Foreign country	Yes	Yes	Yes	Yes
Home country	Yes	Yes	Yes	Yes
Pseudo *R*-squared	0.196	0.180	0.192	0.182
Observations	274,474	274,474	275,293	275,293
of which censored at 0	253,191	253,191	251,345	251,345
of which uncensored	21,283	21,280	23,948	23,945
of which censored at 100		3		3

Notes: This table replicates Table 4 and adds control variables for the comparative advantage of the home and foreign countries. Columns (1)-(2) and (3)-(4) show results for Scope 1 and 2 emissions, respectively. Regressions are estimated as Tobit regressions. $SEER_{ht}-SEER_{ct}$ is our proxy for stringency and enforcement of environmental regulation in the home (h) minus the foreign country (c), with higher values indicating stricter regulation at home. CA(Skill) and CA(Capital) are our additional controls for comparative advantage in skilled labour and capital, respectively, of the firm's industry in the home or foreign country. All regressions include home country and foreign country fixed effects. Standard errors are clustered by country-pair. 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.

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