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Assessing the Effects of Climate Policy on Firms' Greenhouse Gas Emissions

Markus Zimmer¹ and Ana Maria Montoya Gómez²

Abstract

We study the effect of climate policy on companies' GHG emissions using emissions data for the headquarters and subsidiaries of the world's biggest manufacturing, energy, and utility companies. Our results suggest that financial incentives and legal requirements to audit energy use, as well as loans and subsidies aimed at increasing the use of renewable energy sources for electricity generation, reduce companies' emissions, whereas support schemes aimed at increasing combined generation of heat and power have a positive effect on non-utility companies.

1. Introduction

Growing concern over global warming has resulted in an increasing number of national policies designed to slow or halt climate change over the past quarter-century. Yet, the global public good character of the climate raises concern that these unilateral efforts fall short of effectively addressing greenhouse gas (GHG) emissions. Aside from the potential catastrophic consequences of climate change in the long run, ineffective policies can have detrimental effects in the more immediate future because every policy implementation requires effort and resources that could have been directed toward other uses.

It is important to assess the effectiveness of implemented climate policies so as to learn from past experiences and improve instruments found ineffective at reducing emissions. Toward this end, scholars have engaged in ex-post analyses of specific climate policies (e.g., Haug et al.'s, 2010 analysis of studies evaluating different policies; Abrell et al., 2011; Martin et al., 2014). Although analysis of single measures is important for adjusting policies, equally valuable are cross-country approaches that provide information on whether climate policies

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have been successful in reducing emissions and on which type of policies are generally more effective. To date, however, such an international assessment has not been conducted.

Another issue of particular interest is the effect of such policies at the micro scale of single firms and the interaction of these policies with each other and with non-policy-driven mitigation efforts by companies. Again, however, not much empirical work has been devoted to discovering policy effects on firms' GHG emissions nor to the simultaneous assessment of different policies that would enable discovering the unique effect of each measure.

Thus, we expand the literature in three dimensions. First, we study the effect of climate policy at the microeconomic level by examining firms' emissions. Second, we assess several policy types simultaneously to obtain a direct comparison of the measures. Finally, our cross-country approach makes it possible to give a general answer to the question of whether climate policy has been effective.

We use firm-level emissions data collected through surveys by the Carbon Disclosure Project (CDP) and policy measures contained in the Policies and Measures Database of the International Energy Agency. The policies analyzed consist of financial incentives to increase the use of renewable energy sources in electricity generation, the use of combined heat and power generation technologies (CHP), and energy efficiency improving measures. Our analysis focuses on the largest global manufacturing, energy, and utility companies and their operations in 39 OECD and BRICS countries. The final sample covers emissions by about 1,250 company-year pairs (7,800 subsidiary-year pairs) for the period 2007–2012. Total emissions in the sample comprised almost 25% of the total emissions of OECD and BRICS countries in 2007.³

The assessment is based on econometric regressions, where changes in companies' emissions are explained by a set of variables indicating the number of a certain policy measure introduced in the respective country in the last two years. Moreover, in order to separate the business-as-usual (BAU) emissions from the policy effect, companies' economic activity is considered by including their revenues as a control variable. Other characteristics, including firm size, industry sector, and home country, are also considered as determinants of emissions. However, the voluntary nature of emissions disclosures to CDP raises concern about the representativeness of the data. If companies self-select into disclosure and nondisclosure based on the level of their emissions, the sample will be biased and so will the

³ Own calculations based on WRI (2016), CDP waves 2008–2013, and UNFCCC (2016).

results. Therefore, to test and correct for sample selection, a Heckman procedure is implemented in additional regressions.

The rest of this paper is organized as follows. Section 2 reviews the literature on the effectiveness of general environmental regulation and specific climate policy measures at the industry or firm level. Emissions, policy, and other corporate and country data used for the analysis, as well as their sources and descriptive statistics, are described in Section 3. Section 4 introduces the model for identifying the effect of climate policy on firms' emissions, and includes a discussion of endogeneity-related issues and how they are addressed in this study. Results of the econometric regressions are presented in Section 5. Section 6 contains concluding remarks and suggests several possible extensions of the analysis.

2. Related Literature

To the best of our knowledge, no study has yet compared the effectiveness of different climate policy measures using firm-level data from several countries. Thus, the literature related to our study tends to investigate just one of the aspects of this issue, whereas our approach looks at its international scope, firm-level emissions, and how these are linked to different types of climate policy. Some authors study the effectiveness of specific climate policies in individual countries or in a group of countries subject to the same policy measure, for example, the European Union Emissions Trading System (EU ETS) (Abrell et al., 2011; Martin et al., 2014). Using panel data in relation to the economic characteristics of the plants from the U.K. production census and detailed information on their energy use from the Quarterly Fuels Inquiry, Martin et al. (2014) study the impact of the Climate Change Levy (CCL) package on energy consumption and energy intensity of manufacturing plants in the United Kingdom for the period 2001–2004. The CCL consists of an energy tax with differentiated rates applied to coal, gas, electricity, and non-transport liquefied petroleum gas. The authors find that the CCL induced a reduction in plants' energy intensity. Specifically, they detect a decrease in electricity consumption of about 23% and a negative impact of CCL on the sum of emissions across fuel types (Martin et al., 2014).

Another study in this category is that by Abrell et al. (2011). They analyze emissions and economic data of firms covered by the EU ETS during the first phase and the beginning of the second phase of the system, thus providing an ex-post assessment of the scheme's effectiveness at the firm level. The authors make use of the structural break between the first

two phases, manifested as a tighter overall cap in the second phase and the possibility of banking allowances for future phases, which the authors presume should have led to changes in the firms' emissions behavior. They find that emission reductions in the analyzed years of the second phase were not attributable to changes in economic circumstances only. Even after controlling for economic activity and economic environment, emission reductions between 2007 and 2008 were 3.6% larger than between 2005 and 2006.

International comparisons that allow testing the generalizability of country-level findings are rare. Harrington et al. (2004) take a step in this direction by providing 12 detailed case studies assessing, among other things, the effectiveness as well as the static and the dynamic efficiency of command and control versus economic incentives instruments dealing with environmental problems. The case studies were selected such that similar environmental problems were addressed using different policy types in the United States and Europe (Harrington et al., 2004).

Harrington et al. (2004) hypothesize that objectives are achieved with greater certainty and more quickly when regulatory instruments are employed. On the one hand, it seems clear that this hypothesis should hold true for emission taxes, due to the uncertain degree of emission reductions associated with a particular tax level. On the other hand, even though both a cap-and-trade system and an emission standard may have the same emissions cap, overall emissions will be lower under the latter policy approach. The authors explain this by the fact that plants generally overcomply under direct regulation, while marketable permits allow surpluses to be traded to emitters that will use them (Harrington et al., 2004).

Analysis of the case studies did not allow the authors to clearly identify the comparative effectiveness of the instruments. In some cases, incentive-based policies were as effective as prescriptive approaches, while in other cases the former had some design problems that hampered their appropriate performance (Harrington et al., 2004). Harrington et al.'s (2004) experience in trying to compare the case studies illustrates that although a case study analysis would appear to be a promising method of assessing policies in different countries, the results of the comparison may be far from unambiguous. In this paper, we employ an econometric approach capable of assessing different policy types simultaneously and control for relevant country and firm characteristics, thus enabling us to single out the effect of each policy type on corporate emissions, while allowing comparability across policies.

3. Data

3.1 Description

3.1.1 Emissions and Participation Data

In investigating the effects of national climate policy on corporate emissions, it is vitally important that GHG emissions information is available on a country basis and not only as a global total. Emission figures of firms at the country level for the period from 2003 to 2012 were obtained from the Carbon Disclosure Project (CDP).⁴ Emissions are expressed as metric tons of CO₂-equivalent (CO₂e) and consist of the so-called scope-1 emissions, that is, emissions from sources that are controlled or owned by the company (Greenhouse Gas Protocol, 2014). The time period of the analysis was selected on the basis of the completeness and quality of emissions data. Thus, since there is a great deal of information missing from the CDP waves of 2003 to 2007, only the waves since 2008 were included in the analysis.

CDP's datasets also provide information on the industry sector, the company's country of incorporation, the company's International Security Identification Number (ISIN), and the CDP's account numbers. The latter were used to map CDP data across years, since responses to each CDP wave are in separate workbooks. Account numbers were not available in the workbooks prior to 2010; thus company names were used to match companies to account numbers from later CDP waves.

In the data preparation process some assumptions were made in order to allow comparability of the data. First, as some companies' reporting periods do not always coincide with calendar years, it was necessary to decide on a rule for assigning their emissions to a specific year. It seems sensible to assign emissions to the year that coincides most with the actual emissions period. So, for instance, emissions that were reported for the period between August 1 of year t and July 31 of year $t+1$ were assigned to calendar year $t+1$.

CDP questionnaires allow reporting emissions for more than one year, which has two consequences for data availability and completeness. On the one hand, even if companies do not report emissions for one year, for example, due to lack of information, they are still able to do so in a future CDP wave when information becomes available. On the other hand, it was

⁴ CDP is a not-for-profit organization that collects voluntarily-given information on corporate emissions, energy use, and attitudes toward climate change from the largest companies in the world as well as from the largest companies in selected regions or countries. Table A.1 in Annex I provides, as an example, the number of companies per country and region that were asked to report on climate change through CDP in 2013.

observed that companies reported emissions for the same year in different CDP waves, indicating that firms corrected their calculations as more information became available to them. After merging all CDP waves, this phenomenon resulted in “duplicate” observations with respect to firm, country, and year. Considering that more recently disclosed information was likelier to be correct, the oldest observations were eliminated from the dataset.

There are three issues with CDP data that might have consequences for the analysis. First, the voluntary character of CDP surveys raises the concern that companies might self-select into disclosure and nondisclosure depending on the level of their emissions. The consequence for this study would be that the sample on which the analysis is based would not be representative, leading to a biased analysis. To control for self-selection it is necessary that—except for emissions—the same information set is available for respondents and non-respondents. Thus, CDP, upon our request, provided an additional dataset containing basic information (name, identification number, and sector) for all companies invited to participate in their surveys and the response status of each (i.e., either participated or not).

Second, the group of firms asked to report their emissions is not chosen randomly but based on company size. This could be another source of selection bias, though in this case it would be generated by the sampling methodology and not by firms’ decisions. Fortunately, this potential problem is easily addressed by including the variable on which selection is based as an explanatory variable in the model, as will be shown in Section 4.1.

Third, the fact that emissions at the country level are obtained by asking firms to provide a country breakdown of their total global emissions indicates that disclosure decisions are not made in the individual countries where emissions are released but, for example, at the company’s headquarters. This can have consequences for estimation, since in the process of correcting for self-selection, companies reporting emissions for several countries will be more heavily weighted than firms reporting for only one country or firms not disclosing at all. Thus, disclosing companies are more heavily weighted than non-disclosing ones, since the latter show up only once per year and the former several times, depending on the number of emitting units for which the companies are reporting. To eliminate this bias, we use data from Bureau van Dijk’s Orbis dataset indicating the countries in which each of the companies has subsidiaries. Since we are dealing with the largest companies in the world, ownership structure is complex and the spectrum of industries in which each of the ultimate parent companies is involved can be wide. Thus, so as to give our inquiry a consistent structure, we consider only those subsidiaries for which the company in our initial dataset is a majority

owner. Moreover, only subsidiaries whose two-digit NACE code coincides with the two-digit NACE code of the parent company are included. Ownership relations as of the end of 2012 were assumed for the entire sample period.

3.1.2 Policy Measures

Data on policy measures implemented in different countries are from three databases of the International Energy Agency (IEA, 2015): the *Addressing Climate Change Database*, the *IEA/IRENA Global Renewable Energy Policies and Measures Database*, and the *Energy Efficiency Database*. The policies are sorted by goal and similarity of the policy types. Table 3.1 provides a description of the types of policies in the different groups.

Table 3.1: Policy variables

Category/ Variable	Target	Description
RES loans and subsidies	Increase the use of renewable energy sources for electricity generation	Loans at reduced or market interest rates, grants, subsidies, and tax relief
RES feed-in tariffs	Increase the use of renewable energy sources for electricity generation	Feed-in tariffs
CHP	Expansion of combined generation of heat and power	Grants, subsidies, and loans
Energy audits	Auditing the energy use of companies	Financial incentives or legal requirements
EE loans and subsidies	Increasing energy efficiency	Loans at reduced or market interest rates, grants, subsidies, and tax relief

Source: Own compilation based on IEA Policies and Measures Databases.

The final dataset contains the number of policy measures of every type implemented per year and country during the period 2007–2012 for 39 OECD and BRICS countries. Although it is clear that specific design and implementation details are important determinants of a policy’s effectiveness, this count variable approach, together with a dummy variable approach, is one of the few means available for achieving comparability across countries given the current scarcity of data. During the data collection process it was assumed that a type of policy was not implemented in a certain country if for that country none of the consulted databases listed a policy measure that could be assigned to that subcategory. Although this is a plausible

assumption, there remains the possibility that a policy measure exists but is not listed in the databases, especially in countries for which data availability was poor.⁵

3.1.3 Further Corporate and Country Data

Revenue data are available only for the companies that responded to the CDP survey (i.e., this information is not available for those companies that chose not to participate). However, to control for self-selection, revenue data are needed for the non-respondents and the Thomson Reuters' Thomson.One Banker dataset was used to this end. Since some companies' fiscal years differ from calendar years, revenue data were assigned to a calendar year using the same rule as for emissions data. Thus, revenues of companies whose fiscal year ended between August 1 of year t and July 31 of year $t+1$ were assigned to calendar year t . Market capitalization figures were retrieved as of December 31 of the year before each CDP wave.

Because companies, and also the Thomson.One Banker dataset, report financial data in the respective country's currency, these figures were converted to USD using the official exchange rates calculated as an annual average and reported by the World Bank in its World Development Indicators dataset (World Bank, 2014). The resulting revenues and market capitalization figures are expressed in million USD. To obtain real figures and be consistent in terms of basis year and currency, revenues and market capitalization data were deflated using the GDP deflator of the U.S. Bureau of Economic Analysis with basis year 2009 (US BEA, 2013).

Ideally, revenue information should correspond to the company's activity in each country, thus allowing calculation of emission intensities for each emitting unit, that is, how many tons of CO_{2e} per USD revenue they emit. However, only figures for the entire company were available and so a weighting procedure was implemented to proxy for specific-country revenues. The weighting factor for each company-country pair was calculated by dividing the number of subsidiaries a company has in each country by that company's total number of subsidiaries. Subsequently, the worldwide revenue of the company was multiplied by the corresponding company-country weighting factor.

Other data needed to control and correct for potential self-selection were extracted from Thomson Reuters' ASSET4 Environmental, Social and Corporate Governance (ASSET4 ESG) Dataset. ASSET4 gathers publicly available information from corporate social

⁵ Brazil, Chile, Slovenia, and Iceland are countries for which data availability was less than optimum.

responsibility reports, company websites, annual reports, and NGOs on over 250 performance indicators (Thomson Reuters, 2012). The extracted variable indicates whether a company monitors the protection of human rights in its facilities or those of its suppliers.

3.1.4 Matching Process and Resulting Sample

Emissions, financial data, and ASSET4 indicators were merged using CDP account numbers and years. Subsequently, policy and other country-specific data were matched to company data by country and year. For expositional reasons the combination country-of-emissions-company will be referred to below as a *subsidiary*.

Since financial and ASSET4 data were not available for all observations, the initial sample of over 80,000 observations was reduced to a final unbalanced sample of about 53,700 observations. More details on the data are provided below.

3.2 Descriptive Statistics

Summary statistics are set out in Table 3.2. The *Subsidiary level* panel reveals that the average subsidiary in the sample has a yearly revenue of one billion USD and emits around 1.1 Mt CO_{2e} a year. *Disclosing emissions* is the dependent variable in the first-stage regression of the Heckman procedure and takes the value 1 whenever country emissions were disclosed in two consecutive years. Its mean tells us that out of 52,618 observations we have the CO_{2e} emissions levels for 13% of the subsidiary-years in the final sample, corresponding to 6,735 observations. Moreover, there is significant variation across all policy variables.

The *Corporate level* panel of Table 3.2 shows descriptive statistics for the whole corporation. The revenues of the average company in our sample amount to 10,7 billion USD and its market capitalization value is 10 billion USD. The statistic for the human rights monitoring variable indicates that 16% of the corporations in the sample monitor human rights on their premises and, as we can observe after additional calculations, 27% of total number of observations are subsidiaries to these companies. In addition, significant variation is observed for each variable in Table 3.2.

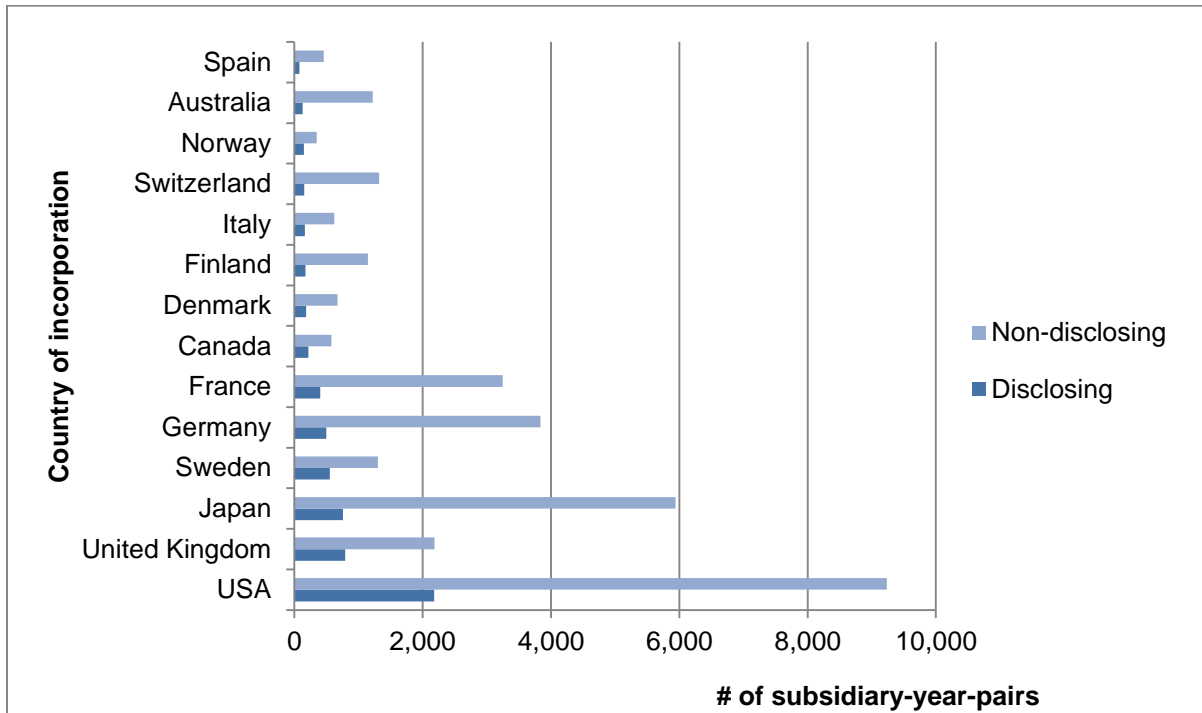
Table 3.2: : Descriptive statistics

	Mean	Std.Dev.	Min	Max
<i>Subsidiary level:</i>				
Disclosing emissions	0.13	0.33	0	1
Metric tonnes CO2e	1,114,895.23	6,176,835.67	.7	156,300,000
Weighted revenues, million USD	993.30	4,231.08	.0035	201,534
<i>Policy variables:</i>				
RES loans & subsidies	0.76	1.34	0	10
RES feed-in tariffs	0.30	0.60	0	3
CHP	0.07	0.31	0	2
EE loans & subsidies	0.21	0.55	0	3
Energy Audits	0.03	0.22	0	2
<i>Corporate level:</i>				
Revenues, million USD	10,771.00	23,740.01	.0035	456,535
Market capitalization, million USD	10,044.46	22,284.05	.0003	475,892
Human Rights Monitoring	0.16	0.36	0	1
Observations	52,618			
Uncensored Observations	6,735			

Notes: Summary statistics for the *Corporate level* panel were calculated considering one observation per company and year, corresponding to a total of 6,600 company-year pairs.

Figure 3.1 illustrates the disclosure behavior of companies registered in selected countries. Most of the subsidiary-years in the sample are attributable to firms registered in the USA, followed by Japanese and German firms. Moreover, firms from these countries comprise 50% of the disclosing company-year pairs. The figure also shows how in all cases the number of censored subsidiary-year pairs is much higher than the number of pairs for which emissions are disclosed.

Figure 3.1: Disclosing and non-disclosing company-year pairs by country of incorporation



Notes: Countries displayed in the figure were selected according to the number of disclosing subsidiaries. Source: Own calculations based on CDP waves 2008–2013.

Since sample selection is assumed, it is interesting to see whether disclosing firms differ significantly from non-disclosing firms. This analysis takes place at the corporation level because the decision to report emissions to CDP is most probably made at corporate headquarters. Sample statistics of company data are drawn for both groups, making sure only one observation per year and corporation enters the calculation. These are presented in the *Corporate level* panel of Table 3.3. Disclosing firms are on average twice larger and generate twice the revenues of their counterparts. Thirty-five percent of the disclosing companies monitor human rights protection on their premises; only 11% of the non-disclosing companies do so. Additionally, two-group mean comparison tests are applied to the revenue, market capitalization, and human rights monitoring variables. With a p-value below 0.001 the results indicate that in all three cases the hypothesis that the averages for the disclosing and non-disclosing group are equal can be rejected. Thus, firms with higher revenues, those that are larger, and those that monitor human rights are more likely to report their emissions. Moreover, the mean comparison test applied to weighted revenues (see *Subsidiary level* panel of Table 3.3) indicates that subsidiaries for which emissions have been disclosed by their

parent companies are larger in terms of revenue than are subsidiaries for which no emissions data are available.

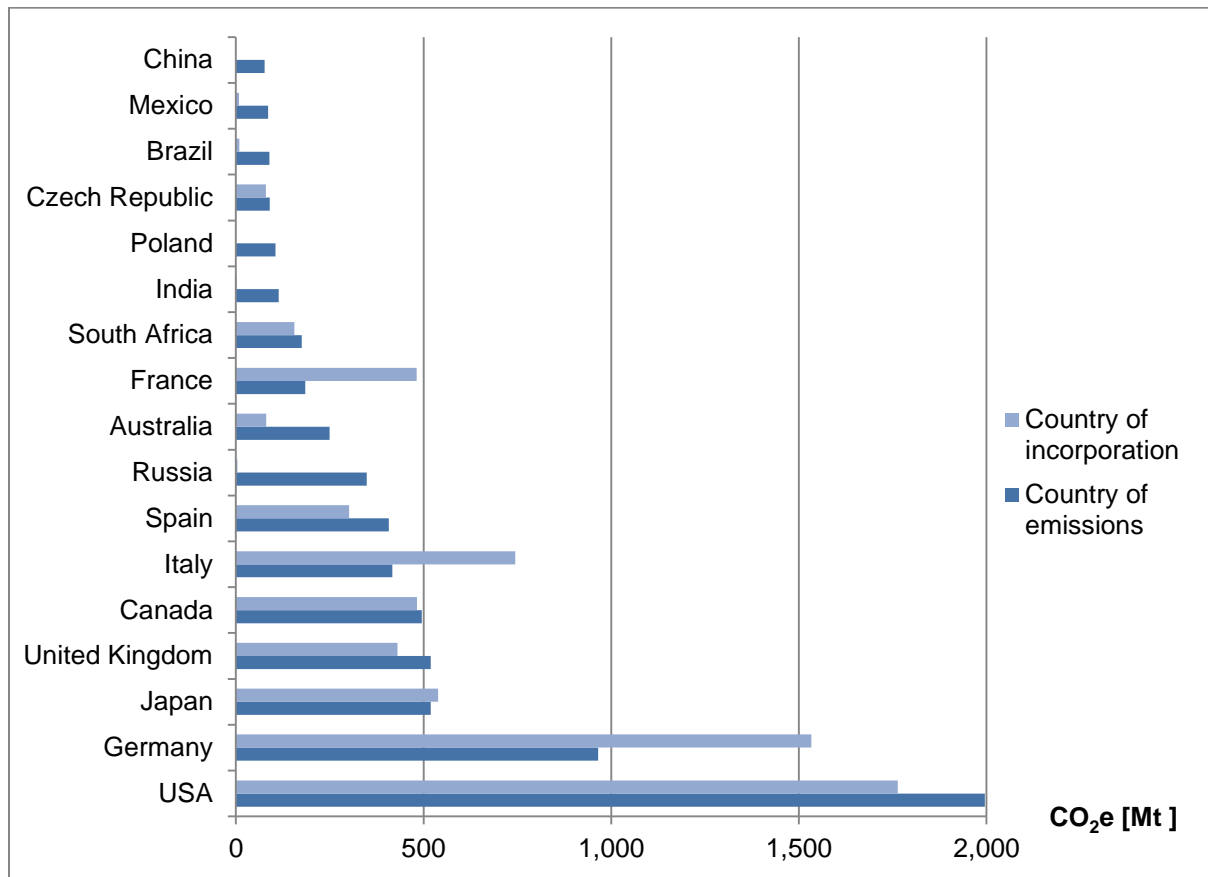
Table 3.3: Differences between disclosing and non-disclosing firms

	Not Disclosing	Disclosing	Mean Diff.
<i>Subsidiary level:</i>			
Weighted revenues, million USD	862 [3,892]	1,887 [5,978]	1,025*** (55)
<i>Corporate level:</i>			
Revenues, million USD	8,951 [21,818]	18,052 [29,123]	9,102*** (722)
Market capitalization, million USD	8,272 [21,194]	17,113 [24,971]	8,842*** (677)
Human Rights Monitoring	.11 [.31]	.35 [.48]	.24*** (.011)
Observations subsidiary level	45,883	6,735	52,618
Observations corporate level	5,280	1,320	6,600

Notes: The *Mean Diff.* column reports the significance levels of a two-group mean comparison test with unequal variances, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard deviation in brackets, standard error in parentheses. Statistics for the *Corporate level* panel were calculated considering one observation per company and year.
Sources: Own calculations based on CDP waves 2008–2013, Thomson.One Banker, Orbis, and ASSET4.

Figure 5.2 is the result of taking a closer look at the disclosing companies and their emissions in each country. Out of the 7,330 Mt CO₂e released by the companies in the sample between 2007 and 2012, emissions of close to 2,000 Mt CO₂e took place in the USA, over 900 Mt in Germany, and over 500 Mt in both Japan and the United Kingdom. Although it is tempting to make sweeping statements as to how dirty or clean companies are in different countries, Figure 5.2 makes evident the folly of doing so. On the one hand, the number of emitting units differs dramatically. While in the USA GHG are released by about 800 subsidiary-year pairs, in Brazil 266 observations were responsible for the 88 Mt emitted in that country during the sample period. On the other hand, we do not know how a company’s production is distributed among subsidiaries, and it is therefore not possible to calculate emission intensity figures.

Figure 3.2: Total emissions by country of emissions and country of incorporation (selected countries)



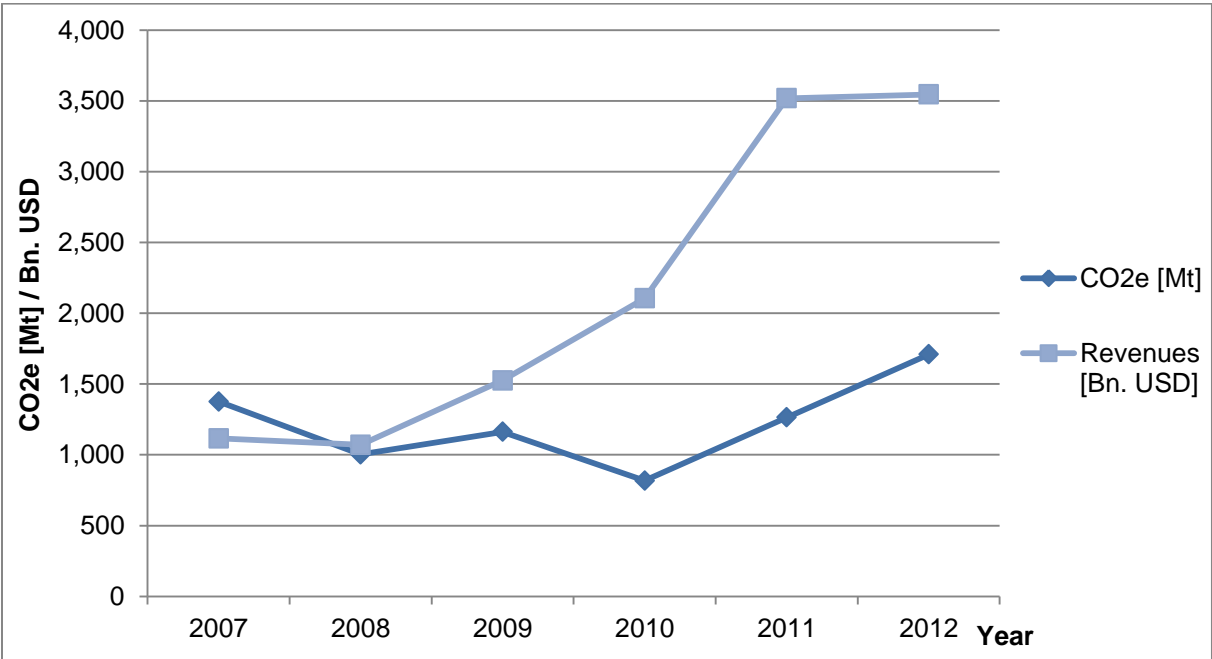
Notes: Countries displayed in the figure were selected according to the level of emissions released by companies located in their territory.

Source: Own calculations based on CDP waves 2008–2013.

Figure 3.2 also displays emissions released in each country and emissions that can be attributed to companies incorporated in the same country. So, for instance, German companies emitted 1,533 Mt CO₂e across all OECD and BRICS countries—as indicated by the light blue bar—while emissions amounting to 965 Mt CO₂e were released in Germany by subsidiaries of companies incorporated in Germany or any other country. The difference between the two bars for each country might be viewed as a sort of emissions balance: for example, German, French, and Italian companies emit more in OECD and BRICS countries than is emitted in their territories, while the opposite holds for the USA, the United Kingdom, and Spain. However, we should bear in mind the general reporting behavior of companies by country of incorporation (Figure 3.1)—Germany and France are among the countries having the largest number of reporting companies, which means that the emissions balance interpretation of Figure 3.2 should be made with some caution.

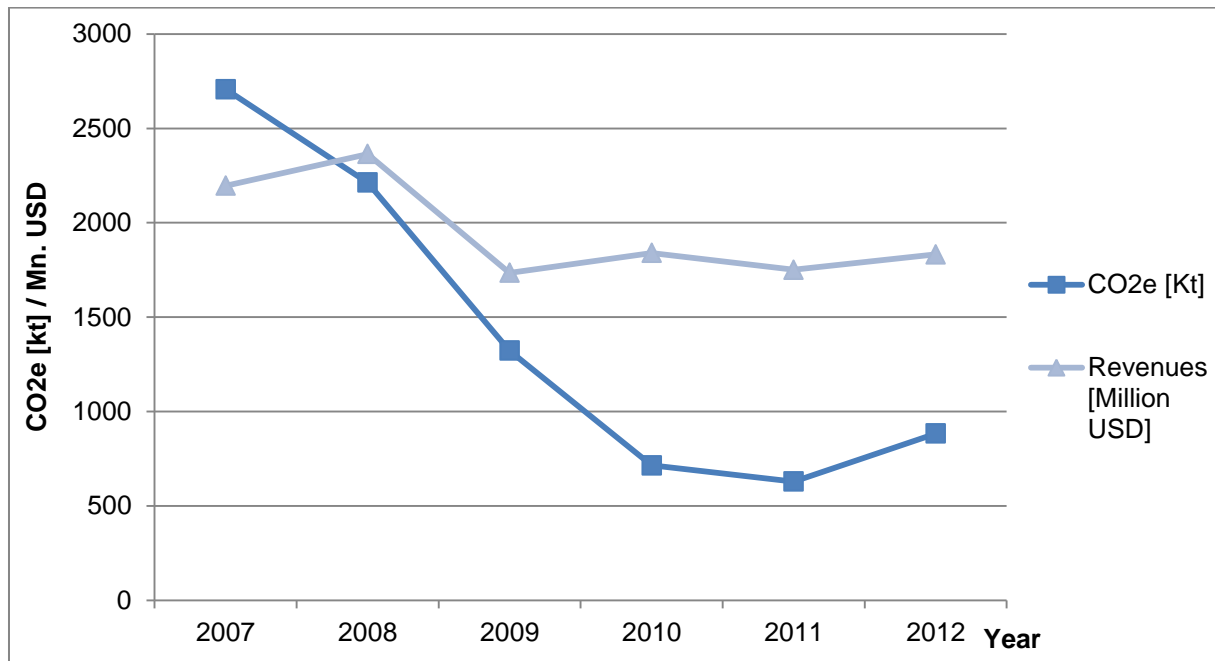
To arrive at some insight into the development of emissions and revenues, total figures per year were calculated by adding up reported emissions across subsidiaries, on the one hand, and revenue figures across reporting companies, on the other hand. Figure 3.3 plots these totals. There is an overall upward trend in total revenues, with an acceleration in 2011 followed by a flattening between 2011 and 2012. This pattern of acceleration and flattening of total revenues is most likely due to the increased number of companies for which emissions data were available in 2011 and a return to the pre-2011 level in the year 2012. The figure is informative in the sense that it provides insight into the overall development of emissions and revenues of companies in the sample, but it can be misleading as the number of disclosing firms varies every year. Total revenues and emissions were thus divided by the number of emitting units to calculate the averages and avoid confusing a larger number of reporting companies with increases in emissions or revenues. The resulting plot, presented in Figure 3.4, shows continuously declining average emissions while average revenues remain constant except for the year 2009, during which companies experienced a fall in revenues, probably due to the outbreak of the financial crisis in 2008 and its expansion to the real economy.

Figure 3.3: Development of revenues and emissions (2007–2012)



Notes: Total revenues were calculated using weighted revenue figures.
Source: Own calculations based on CDP waves 2008–2013, Thomson.One Banker, and Orbis.

Figure 3.4: Development of average revenues and emissions (2007–2012)



Source: Own calculations based on CDP waves 2008–2013, Thomson.One Banker, and Orbis.

The different trends observed for average emissions and revenues during the sample period point to a decoupling of these two outcomes of production and indicate that the observed emissions reductions cannot be attributed solely to deceleration of the economy. Whether this apparent decoupling is the result of climate policy will be analyzed in the following section.

4. Model and Methods

4.1 Explaining Emissions

Analyzing the effectiveness of climate policy on firms' emissions involves much more than simply noting upward or downward trends in emissions; it requires considering factors that might explain this development in the absence of regulation. For example, changes in production level are one of the most obvious reasons for changes in emissions and, indeed, have been found by other authors to be a significant predictor of emissions (Abrell et al., 2011). In general, expanding production is accompanied by higher emission levels and vice versa. Therefore, to control for changes in production level, changes in companies' revenues are included as an explanatory variable.

Firm size is also found to be an important determinant of emissions, possibly because larger companies have better access to environmentally efficient technology (Blackman, 2010; Féres and Reynaud, 2012). In this study, market capitalization figures are used as a proxy for firm size. Another reason for taking market capitalization into consideration is that CDP uses this figure as a criterion for participation in its surveys; hence including it in the model as an exogenous explanatory variable prevents selection generated by sampling methodology from becoming an issue. That is, arguably, we are dealing with exogenous sample selection, which causes no harm to the estimation (Wooldridge, 2009).

We could consider the direct and indirect effect of informal regulation on pollution, which is shown in some studies to be non-negligible (Cole et al., 2005; Féres and Reynaud, 2012). However, community pressure on both polluters and regulators is likely to be limited in the special case of GHG, as the local effect of emission by companies located in a specific area is so small that it is hardly perceivable by the community. In fact, Cole et al. (2005) find that informal regulation has very little influence on CO₂ emissions; thus this type of regulation is not considered in the present analysis.

Cap-and-trade schemes should have a negative impact on emission levels, as long as the caps have been wisely set. Therefore, although we do not analyze the performance of emission trading systems, it is important to take into account whether a subsidiary is covered by an emissions trading system when assessing the effectiveness of other policy instruments in order to avoid obtaining biased results for the latter.

The relationship between changes in emissions and the above-discussed determinant factors can be expressed as:

$$\ln CO2_{it} = \beta_r \ln REV_{it} + \beta_m \ln MKTC_{it} + \beta_p \mathbf{POL}_{ct} + \beta_e ETS_{it} + u_{it}, \quad (4.1)$$

where $CO2_{it}$ is GHG emissions of emitting unit i in year t , REV_{it} represents deflated revenues, and $MKTC_{it}$ is deflated market capitalization. \mathbf{POL}_{ct} is a vector of variables capturing the different policy measures in country c with which firms are confronted, that is, the variables of interest. Each policy variable counts the number of measures implemented in the current and past year. ETS_{it} is a dummy variable indicating whether the subsidiary is covered by the EU emissions trading system and is not included in the policy vector due to its role as a control variable. The error term is represented by u_{it} .

Equation (4.1) represents the relationship of interest, yet estimating it with OLS could lead to biased estimates due to three potential sources of endogeneity: measurement error, unobserved heterogeneity, and self-selection. Each is discussed below.

First, it seems likely that at least some of the firms do not report their real emissions, either because they do not have complete information or because, for various reasons, they deliberately choose to exaggerate or underreport. For example, they might report inflated emission figures if they expect climate policies based on their past emissions to be implemented in the near term. This would be the case for an emissions trading system that allocates allowances based on the companies' historical emissions, so that overreporting emissions would grant firms access to more allowances in the future. However, this is unlikely to be the chief consideration when disclosing emissions to CDP, simply because it is not an official data source on which regulation is based. On the other hand, underreporting would make companies appear cleaner, not only to communities and customers, but also to investors. Since the expected implementation of certain policy measures might affect the profit prospects of the concerned companies, investors should, in theory, consider a firm's emissions level in their risk assessments and be less interested in "dirty" companies (Schweizer Pensions- & Investmentnachrichten, 2012). Thus, it seems more reasonable that measurement error would go in the direction of companies underreporting their emissions, with the consequence for the estimation being that the effect of climate policy appears to be smaller than it actually is, that is, measurement error will cause attenuation bias.

The second potential source of bias, the one arising from unobserved heterogeneity, is addressed by analyzing the first differences of the emissions, revenue and market capitalization logarithmic values instead of the logarithm, which goes beyond the control for firm characteristics and takes care of unobserved subsidiary features.

The last measure to control for unobserved heterogeneity consists in including a full set of year dummies, which is particularly important considering that the period of analysis includes the turbulent years following the financial crisis in 2008.

The third source of endogeneity arises from the fact that our emissions data are taken from a survey in which many companies did not participate and some of those that do, do not provide information on their emissions, resulting in a nonrandom sample. As this issue is the main methodological challenge for the present study, next subsection is dedicated to analyzing the selection problem and discussing the measures taken to address it.

With respect to the policy variables, an important implication of the fact that measures of the type *RES loans and subsidies*, or *RES Feed-in tariffs* are aimed at increasing the use of renewable energy sources (RES) for electricity generation is that they presumably more strongly influence the emitting behavior of companies in the *Utilities* sector than the emissions of manufacturing companies. A similar consideration applies to grants, loans, and subsidies for combined heat and power (*chp*). Since policies of the *chp* type target electricity and heat generation, their effect on utilities' GHG emissions is expected to differ from their effect on other sector emissions. To take these factors into consideration, the above mentioned policy variables will enter the analysis interacting with the dummy variable identifying utility companies.

Thus the policy vector in Equation (4.1) should be:

$$\mathbf{POL}_{cit} = \begin{pmatrix} reslosu_{ct} \\ Dut_{it} \times reslosu_{ct} \\ resfit_{ct} \\ Dut_{it} \times resfit_{ct} \\ chp_{ct} \\ Dut_{it} \times chp_{ct} \\ ind_audit_{ct} \\ eesubs_{ct} \end{pmatrix},$$

where $reslosu_{ct}$, $resfit_{ct}$, chp_{ct} , ind_audit_{ct} , and $eelosu_{ct}$ represent the policies described in Table 3.1 and Dut_{it} is the dummy variable identifying companies in the *Utilities* sector.

So far, the relationship of interest expressed by Equation (4.1) has become:

$$\Delta \ln CO2_{it} = \beta_r \Delta \ln REV_{it} + \beta_m \ln \Delta MKTC_{it} + \beta'_p \mathbf{POL}_{cit} + v_{it}^E, \quad (4.2)$$

where v_{it}^E represents the error term in this new setting.

4.2 Controlling for Self-Selection

The self-selection problem arises because data on a key variable are missing as a result of the outcome of another variable, namely, disclosure (Wooldridge, 2002). If firms made their disclosure decision randomly, there would be no reason for concern. However, it seems likely that companies base their disclosure decision on their own level of emissions. For example, cleaner companies might be proud to disclose their emissions information, whereas dirtier companies might wish to keep this information private. If this is indeed the case, the sample of reported emissions is downward biased. There are also good reasons to believe that

companies active in some specific sectors or incorporated in a given country are more prone to disclose their emissions. For instance, firms active in a sector that is subject to regulation mandating the reporting of emissions may be more likely to disclose their emissions in the survey because they have already compiled the figures. Thus, the outcome of the disclosure decision is likely to be related to other regressors and to the dependent variable, which means that ignoring the issue could give rise to an omitted variable bias, as pointed out by Heckman (1979).

Therefore, to control for the selection problem, a Heckman procedure is applied, which involves the estimation of two equations, in our case a disclosure equation and an emissions equation. Although not strictly necessary for identification, the disclosure equation includes an instrument that allows more precise estimation of the coefficients in the emissions equation by avoiding large standard errors resulting from the severe collinearity that would be introduced in the regression if both equations contained exactly the same set of regressors (Heckman, 1976; Wooldridge, 2002). Our instrument is a measure of the company's engagement in monitoring human rights (*HR*). An important condition is that the instrument must be related to disclosure but not to emission changes, either directly or indirectly through unobservable variables contained in the error term v_{it}^E .

Since monitoring is a prerequisite to disclosure, *HR* provides us with valuable information on a firm's overall commitment to monitor and report on aspects beyond the financial sphere. Therefore, it is a relevant variable for explaining a company's willingness to disclose greenhouse gas emissions. The validity of *HR* as an instrument is motivated by the fact that monitoring human rights has no relationship to GHG emissions, since it represents a social rather than an environmental concern. Nevertheless, it could be that companies that care about the environment also care about social aspects and vice versa. Thus, firms that monitor the protection of human rights on their premises would also tend to have lower emissions levels. There are two main reasons that give us confidence in the validity of the instrument. First, the fact that *HR* is measured at the corporation level while emissions are measured at the subsidiary level generates some distance and therefore independence between human rights monitoring decisions and decisions concerning emissions behavior. Still, note that this does not affect the connection between *HR* and emissions disclosure since they are both measured at the corporate, that is, at the headquarters, level. Second, it seems implausible that the instrument is in any way related to changes in emissions levels, which is the variable we are aiming to explain. There is no appropriate way of testing the exclusion restriction, but we can,

and did, check whether there is a significant correlation between human rights monitoring and emissions changes. No significant correlation was found; thus, we can rule out an obvious violation of the restriction.

There are two ways of estimating a Heckman model, the first is a two-part procedure involving a probit estimation of the selection equation (disclosure equation) and a subsequent ordinary least squares (OLS) estimation of the emissions equation. The second way involves maximum likelihood (ML) estimation of both equations. We opt for the former method in order to be able to cluster the standard error at the country level to account for the fact that the correlation of the policy variables within a country is not only high but perfect.

5. Data Analysis

5.1 Estimation Results

Table 5.1 sets out the estimation results of Equation (4.2). The results in Column (1) correspond to a model estimated on the subsample of emitting units for which emissions figures are available, ignoring the possibility of selection bias. Specification (2) consists of the Heckman procedure.

Comparing the specifications (1) and (2), we see that the significance and the magnitude of the coefficients are maintained irrespective of the estimation method. An important observation from specification (2) is that the coefficient of the parameter $athrho$ is not statistically significant, indicating the absence of self-selection. The results for the disclosure equation are not surprising. They show that human rights monitoring is in fact a relevant predictor of disclosure, as indicated by its highly significant coefficient estimate. Moreover, we see that all else equal, firms monitoring human rights on their premises are more likely to disclose their country emissions. The results also indicate that the probability of disclosure is higher for firms with higher market capitalization, which is in line with the findings by Prado-Lorenzo et al. (2009). Subsidiaries' emissions are also likelier to be disclosed if the subsidiary is covered by the EU ETS, which may be because emitting units subject to emissions trading systems have their emissions information readily available and reporting thus does not require a major effort.

Since we find no evidence that our sample suffers from self-selection bias, the rest of the analysis will deal with the results of the first-differences specification (Column (1) of Table

5.1). An increase in production, proxied in our analysis by revenues, induces an increase in GHG emissions, as expected. Specifically, a 1% increase in revenues implies a 0.19% increase in emissions, holding the other variables constant.

Table 5.1: Regression results FD and Heckman

	(1)	(2)		(3)
	FD Δ Co2 emissions	Heckman Δ Co2 emissions	Disclosure	FD (utilities only) Δ Co2 emissions
RES loans and subsidies t-1	-0.006** (0.003)	-0.007** (0.003)	0.008 (0.016)	
Utility x RES loans and subsidies t-1	0.007 (0.014)	0.007 (0.014)	0.009 (0.035)	-0.009 (0.023)
RES feed-in tariffs t-1	-0.008 (0.006)	-0.008 (0.006)	0.030 (0.041)	
Utility x RES feed-in tariffs t-1	0.070** (0.029)	0.070** (0.029)	-0.068 (0.115)	0.083** (0.031)
CHP t-1	0.029*** (0.008)	0.029*** (0.008)	0.127*** (0.031)	
Utility x CHP t-1	0.030 (0.033)	0.031 (0.033)	0.161** (0.070)	0.022 (0.039)
EE loans and subsidies t-1	0.015 (0.011)	0.014 (0.011)	-0.013 (0.041)	0.008 (0.062)
Energy Audits t-1	-0.045*** (0.012)	-0.048*** (0.012)	0.211*** (0.048)	0.036 (0.056)
Revenue Chg.[log]	0.192*** (0.017)	0.190*** (0.016)	0.004 (0.020)	0.202 (0.128)
Chg Marketcap [log]	-0.005 (0.005)	-0.004 (0.005)	0.058*** (0.016)	0.003 (0.011)
Human Rights Monitoring			0.523*** (0.034)	
athrho		0.0162 (0.532)		
Year FE	YES	YES	YES	YES
Observations	6227	44762		212
Censored		38535		
R2	0.0252			0.0911

Standard errors clustered at the country of emissions level in parentheses

* p<0.10, ** p<0.05, *** p<0.01

Among the results for the policy measures of interest we find that financial incentives and legal requirements for energy auditing have a highly significant negative effect on emissions, so that an additional policy measure of this type reduces emissions by about 4.5%. One

straightforward mechanism that could be driving these results is that, after auditing their energy use, companies realize the cost savings potential of efficiency improvements, and thus implement new emission-reducing measures.

Loans and subsidies aimed at increasing the use of renewable energy sources for electricity generation (*RES loans & subsidies*) reduce emissions by 0,6% on average, as indicated by the significance and sign of the uninteracted coefficient. The interaction of policies of this type with the utilities dummy shows that *RES loans & subsidies* do not have a different effect for utility companies.

The regression results in Table 5.1 indicate that the effect of feed-in tariffs aimed at increasing the use of renewable energy sources for electricity generation have a different effect on utilities' emissions than on other companies' emissions. Column (3) in Table 5.1, where we present the results of the regression on the subpanel of utility companies shows that overall this policy type increases utilities' emissions by 8.3% on average and that this effect is statistically significant. Although this finding might be surprising at first, it can be explained considering the technology portfolio of traditional utility companies and observations from the German electricity market, where we saw an increase in CO₂ emissions per generated kilowatt hour between 2010 and 2012 (German Federal Environmental Office, 2015). The mechanism driving these results might be as follows. Since cleaner, more expensive fossil fuel power stations are placed at the end of the merit order, an increased generation from RES (which are financed by feed-in tariffs and have preferential entry into the electricity network) crowds out cleaner fossil fuel power stations from the wholesale market. As a result, traditional utility companies' generation is now dirtier on average. The use of the German example as an explanation might lead the reader to think that the results are specific to Germany, yet running the regression without subsidiaries located in that country generates the same results. This result shows that well-intentioned policies can lead to unintended outcomes, at least in the short run, by inducing behavioral changes in the market actors.

Support schemes for CHP have a positive effect on emissions of non-utility companies, while they do not seem to have any effect on the emissions of utility companies, as shown by the interacted coefficient and the results presented in Column (3) of Table 5.1. The results can be seen as an indication that the introduction of CHP support schemes leads to an increase of about 3% in the emissions of companies in other sectors. A possible mechanism driving this result may be that the support scheme incentivizes companies that are not in the utilities sector and formerly used to purchase heat and power to engage in power and heat generation for

their own use. While this “new product” increases companies’ emissions, it is not sold and therefore is not reflected in their revenues.

No effect on emissions could be detected in regard to the remaining policy measures, that is, loans and subsidies aimed at increasing energy efficiency. There are at least two interpretations of this lack of effect. First, the financial incentives offered by the government might not be large enough to be considered worthwhile and therefore remain unused. Second, in the case of policies targeting improved energy efficiency, a possible explanation is the (direct) rebound effect. The effect manifests as energy efficiency improvements for a specific energy service causing reductions in the effective price of that service and consequently leading to an increase in its consumption and therefore in emissions. That is, the initial negative effect on energy consumption and emissions would be then partially or totally offset by the effect of the reduced effective price (Brännlund et al., 2007; Sorrell and Dimitropoulos, 2008). In the context of this study, such findings imply that energy efficiency improvements resulting from *EE loans and subsidies* could be totally offset by the rebound effect.

A third interpretation of the lack of significance of the effect of some policy types in emissions, might be the time lag between implementation of a policy and companies using the offered support schemes. We extend the analysis by also including policies implemented two and three years prior to the measurement of emissions as presented in columns (2) and (3) of Table 5.2. The first column contains the results presented in Column (1) of Table 5.1 to facilitate comparison. We see that the results for the policies implemented in $t-1$ remain stable as we include additional lags, with exception of RES loans and subsidies. This is reassuring because we can be confident that by performing the analysis as in column (1), we are not capturing the effects of policies implemented in the past. From this extension we learn that in the case of CHP, emissions decrease again after an initial increase following the implementation of this type of policy. Moreover, we observe a negative and significant effect of loans and subsidies to increase energy efficiency in the second period after implementation, which could not be identified in the first period.

Table 5.2: Extended time pattern of policy effects

	(1)	(2)	(3)
RES loans and subsidies t-1	-0.006** (0.003)	-0.005* (0.003)	-0.003 (0.003)
RES loans and subsidies t-2		0.001 (0.003)	-0.000 (0.003)
RES loans and subsidies t-3			-0.004 (0.004)
Utility x RES loans and subsidies t-1	0.007 (0.014)	0.005 (0.015)	-0.001 (0.014)
Utility x RES loans and subsidies t-2		-0.010 (0.016)	-0.002 (0.011)
Utility x RES loans and subsidies t-3			0.003 (0.009)
RES feed-in tariffs t-1	-0.008 (0.006)	-0.005 (0.006)	-0.008 (0.007)
RES feed-in tariffs t-2		0.004 (0.005)	0.004 (0.005)
RES feed-in tariffs t-3			-0.003 (0.009)
Utility x RES feed-in tariffs t-1	0.070** (0.029)	0.071** (0.030)	0.080*** (0.028)
Utility x RES feed-in tariffs t-2		0.040* (0.020)	0.036* (0.021)
Utility x RES feed-in tariffs t-3			-0.030 (0.066)
CHP t-1	0.029*** (0.008)	0.034*** (0.012)	0.024* (0.014)
CHP t-2		-0.017** (0.007)	-0.010 (0.011)
CHP t-3			0.020* (0.010)
Utility x CHP t-1	0.030 (0.033)	0.023 (0.070)	0.024 (0.051)
Utility x CHP t-2		0.028 (0.034)	0.010 (0.033)
Utility x CHP t-3			-0.138** (0.063)
EE loans and subsidies t-1	0.015 (0.011)	0.015 (0.010)	0.023* (0.013)
EE loans and subsidies t-2		-0.020*** (0.005)	-0.022*** (0.004)
EE loans and subsidies t-3			0.002 (0.010)
Energy Audits t-1	-0.045*** (0.012)	-0.043** (0.018)	-0.043*** (0.014)
Energy Audits t-2		-0.013 (0.016)	-0.010 (0.018)
Energy Audits t-3			-0.029 (0.024)
Year FE	YES	YES	YES
Observations	6227	6227	6227
R2	0.0252	0.0278	0.0295

Standard errors clustered at the country of emissions level in parentheses. All regressions include revenue and market capitalization variables as well as year dummies.

* p<0.10, ** p<0.05, *** p<0.01

5.2 Sensitivity Analysis

By analyzing the sensitivity of the estimated coefficients to specification changes and to the exclusion of specific countries and other groups of observations we rule out a wide set of possible sources of bias. The first set of results is summarized in Table 5.3, where Column (1) is the same as Column (1) in **Fehler! Verweisquelle konnte nicht gefunden werden.** and is included to facilitate comparison.

Table 5.3 shows the results we obtain when each policy type is analyzed separately. Coefficient estimates and their statistical significance remain unchanged. Additional robustness tests consist of excluding different groups of observations. For example, we run several regressions omitting one country at the time and find only minor changes in the significance levels and magnitudes of the coefficients. Alternatively, we trim the dataset based on different thresholds but, again, coefficient magnitudes and significance remain stable.

Finally, the observation that data availability in some countries seems poor challenges the assumption that a policy measure was considered not to be in place in a country if none of the datasets consulted listed the measure for that country. We therefore exclude the four countries with presumably the poorest data availability (Belgium, Brazil, Chile, Slovenia, and Iceland) to verify that they are not distorting the results. The findings do not differ significantly from those in our baseline regression, except for the coefficient of the uninteracted feed-in tariffs variable, whose statistical significance improves.

Table 5.3: Sensitivity analysis—policies

	(1)	(2)	(3)	(4)	(5)	(6)
	FD	FD	FD	FD	FD	FD
	Δ Co2	Δ Co2	Δ Co2	Δ Co2	Δ Co2	Δ Co2
	emissions	emissions	emissions	emissions	emissions	emissions
RES loans and subsidies t-1	-0.006** (0.003)	-0.002 (0.002)				
Utility x RES loans and subsidies t-1	0.007 (0.014)	0.017 (0.013)				
RES feed-in tariffs t-1	-0.008 (0.006)		-0.007 (0.006)			
Utility x RES feed-in tariffs t-1	0.070** (0.029)		0.071** (0.029)			
CHP t-1	0.029*** (0.008)			0.028*** (0.007)		
Utility x CHP t-1	0.030 (0.033)			0.037 (0.030)		
EE loans and subsidies t-1	0.015 (0.011)				0.003 (0.012)	
Energy Audits t-1	-0.045*** (0.012)					-0.038*** (0.012)
Revenue Chg.[log]	0.192*** (0.017)	0.189*** (0.017)	0.188*** (0.017)	0.189*** (0.017)	0.188*** (0.017)	0.190*** (0.016)
Chg Marketcap [log]	-0.005 (0.005)	-0.004 (0.004)	-0.004 (0.004)	-0.004 (0.004)	-0.003 (0.004)	-0.005 (0.005)
Year FE	YES	YES	YES	YES	YES	YES
Observations	7233	7233	7233	7233	7233	7233
R2	0.018	0.017	0.018	0.017	0.017	0.017

Standard errors clustered at the country of emissions level in parentheses

* p<0.10, ** p<0.05, *** p<0.01

6. Conclusions

This paper studied the effect of climate policy on companies' GHG emissions using emissions data for the headquarters and subsidiaries of the world's biggest companies. In our empirical analysis we find three out of the five investigated policy types to have a significant influence on firms' GHG emissions: loans and subsidies aimed at increasing the use of RES for electricity generation, grants and subsidies for CHP, and financial incentives or legal requirements mandating auditing of a company's energy use. The findings are not sensitive to several changes in the model specification.

Our results suggest that financial incentives and legal requirements for auditing companies' energy use, as well as loans and subsidies aimed at increasing the use of renewable energy sources for electricity generation, reduce companies' emissions.

In the case of support schemes for CHP generation, the estimations point to an increase of emissions by companies in non-utility sectors, possibly because these companies now have an incentive to engage in production of electricity and heat for their own use, thus increasing their emissions. This effect reverses in the second year after implementation of the policies. Feed-in tariffs aiming at increasing the use of renewable energy sources for electricity generation seem also to increase utilities' emissions. We explain this effect as the consequence of renewable energy sources crowding out cleaner fossil fuel power stations from the wholesale electricity market what results in traditional utility companies' generation being now dirtier on average. In regard to policies aimed at increasing energy efficiency—our findings suggest that they do not have any effect on emissions in the first period after implementation, yet emissions are reduced in the second year after implementation. This time lag could be due to an initial rebound effect, something worth analyzing more closely.

There are numerous possibilities for extending this analysis, especially considering that, to the best of our knowledge, there are no other similar studies. An invaluable project would involve overcoming data issues. Exerting effort toward collecting a more detailed compilation of implemented climate policy measures (e.g., listing the amount of funding dedicated to each measure) and toward obtaining figures indicating the share of the companies' production taking place in each country would make a more reliable analysis possible.

These data improvements would additionally permit study of other interesting research questions, such as, for example, the assessment of carbon leakage occurring through the investment channel. This phenomenon occurs when climate policy provokes the relocation of

production away from countries with stringent climate policy to countries where climate policy is laxer, undermining the effects of policy measures implemented in the former countries (Babiker, 2005; Felder and Rutherford, 1993; Reinaud, 2008).

This study has shed some light on climate policy effects at the micro level. We hope that more research along these lines will be conducted, as well as that leading to improvement in the availability and quality of data, thus providing a solid foundation for climate policy evaluation.

7. References

- Abrell, J., A. Ndoye Faye, and G. Zachmann (2011), Assessing the Impact of the EU ETS Using Firm Level Data, *Bruegel Working Paper* 2011/08, Brussels, Belgium.
- Babiker, M. H. (2005), Climate Change Policy, Market Structure, and Carbon Leakage, *Journal of International Economics* 65: 421–445.
- Blackman, A. (2010), Alternative Pollution Control Policies in Developing Countries, *Review of Environmental Economics and Policy* 4 (2): 234–253.
- Brännlund, R., T. Ghalwash, and J. Nordström (2007), Increased Energy Efficiency and the Rebound Effect: Effects on Consumption and Emissions, *Energy Economics* 29: 1–17.
- Bureau of Economic Analysis (US BEA) (2013), *Implicit Price Deflator for Gross Domestic Product*. Available at <http://www.bea.gov/iTable/iTable.cfm?ReqID=9&step=1#reqid=9&step=3&isuri=1&910=x&911=0&903=13&904=1990&905=2013&906=a>
- Carbon Disclosure Project (CDP) (2013), *Investor CDP 2013 Information Request*. Available at <https://www.cdp.net/en-US/Programmes/Pages/More-questionnaires.aspx>
- Cole, M. A., R. J. R. Elliot, and K. Shimamoto (2005), Industrial Characteristics, Environmental Regulations and Air Pollution: An Analysis of the UK Manufacturing Sector, *Journal of Environmental Economics and Management* 50: 121–143.
- Felder, S., and T. Rutherford (1993), Unilateral CO₂ Reductions and Carbon Leakage: The Consequences of International Trade in Oil and Basic Materials, *Journal of Environmental Economics and Management* 25: 162–176.
- Féres, J., and A. Reynaud (2012), Assessing the Impact of Formal and Informal Regulations on Environmental and Economic Performance of Brazilian Manufacturing Firms, *Environmental and Resource Economics* 52, 65–85.
- Greenhouse Gas Protocol (2014), *Calculation Tools: FAQ*. Available at <http://www.ghgprotocol.org/calculation-tools/faq>
- Griliches and Hausman (1986), Errors in Variables in Panel Data, *Journal of Econometrics* 31: 93–118.
- Harrington, W., R. D. Morgenstern, and T. Sterner (2004), *Choosing Environmental Policy: Comparing Instruments and Outcomes in the United States and Europe*, Resources for the Future, Washington, DC.

- Haug, C. et al. (2010), Navigating the Dilemmas of Climate Policy in Europe: Evidence from Policy Evaluation Studies, *Climate Change* 101: 427–445.
- Heckman, J. (1976), The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models, *Annals of Economic and Social Measurement* 5: 475–492.
- Heckman, J. (1979), Sample Selection Bias as a Specification Error, *Econometrica* 47: 153–161.
- International Energy Agency (IEA) (2015), *Policies and Measures Databases*, Available at <http://www.iea.org/policiesandmeasures/>
- Martin, R., L. B. de Preux, and U. J. Wagner (2014), The Impacts of the Climate Change Levy on Manufacturing: Evidence from Microdata, *Journal of Public Economics* 117: 1–14.
- Prado-Lorenzo, J. M., L. Rodríguez-Domínguez, I. Gallego-Álvarez, and I. M. García-Sánchez (2009), Factors Influencing the Disclosure of Greenhouse Gas Emissions in Companies World-Wide, *Management Decision* 47 (7): 1133–1157.
- Reinaud, J. (2008), Issues Behind Competitiveness and Carbon Leakage—Focus on Heavy Industry, *IEA Information Paper*, IEA/OECD Paris.
- Schweizer Pensions- & Investmentnachrichten (2012), *Die Dreckspatzen Datenbank*, December 2011–January 2012. Available at <http://www.southpolecarbon.com/public/Swiss%20Pension.pdf>
- Sorrell, S., and J. Dimitropoulos (2008), The Rebound Effect: Microeconomic Definitions, Limitations and Extensions, *Ecological Economics* 65: 636–649.
- Thomson Reuters (2012), *Asset4 Environmental, Social and Corporate Governance Data: Data Collection and Rating Methodology*. Available at http://extranet.datastream.com/data/ASSET4%20ESG/documents/ASSET4_ESG_Methodology_FAQ_0612.pdf
- Umweltbundesamt (2015), *Entwicklung der spezifischen Kohlendioxid -Emissionen des deutschen Strommix in den Jahren 1990 bis 2014*, Umweltbundesamt, Dessau-Roßlau, Germany.
- United Nations Framework Convention on Climate Change (UNFCCC) (2016), Time Series Annex I: GHG Total Excluding LULUCF. Available at http://unfccc.int/ghg_data/ghg_data_unfccc/time_series_annex_i/items/3814.php
- Wooldridge, J. M. (2002), *Econometric Analysis of Cross Section and Panel Data*, The MIT Press, Cambridge, USA and London, England.
- Wooldridge, J. M. (2009), *Introductory Econometrics: A Modern Approach*, 4e, South-Western Cengage Learning, Mason, USA.
- World Bank (2014), *World Development Indicators*. Available at <http://databank.worldbank.org/data/views/reports/tableview.aspx>
- World Resources Institute (WRI) (2016), *CAIT Climate Data Explorer*. World Resources Institute. Washington, DC. Available at <http://cait2.wri.org>.

Appendix

Table A.1: CDP criteria for information request

	Region/sector	Based on	Index used for classification
800 of the largest	Global	market capitalization	FTSE All-World Developed—Large Cap
800 of the largest and mid-sized	Emerging markets	market capitalization	S&P/IFCI Large/Mid Emerging Market Index
725 of the largest	UK	market capitalization	FTSE All-Share and FTSE Fledgling Index
500 of the largest	Global	market capitalization	Global 500
500 of the largest	Japan	market capitalization	
500 of the largest	USA	market capitalization	S&P 500
300 of the largest	Europe	market capitalization	FTSEurofirst 300 Eurozone
260 of the largest	Nordic	market capitalization	
250 of the largest	France	market capitalization	SBF 250
250 of the largest	Germany & Austria	market capitalization	
250 of the largest	Korea	market capitalization	
250 of the largest	Electric utilities globally	market capitalization	
200 of the largest	Australia	market capitalization	ASX 200
50 of the largest	New Zealand	market capitalization	NZX 50
200 of the largest	Canada	market capitalization	
200 of the largest	India	market capitalization	BSE 200
180 of the largest	Issuing bonds	market capitalization	S&P CDS U.S. Investment Grade Index and Markit iBoxx USD Liquid Investment Grade Index
170 of the largest	Asia ex -Japan, India, China, and Korea	market capitalization	Asia ex-JICK
150 of the largest	Netherlands, Belgium, and Luxemburg	market capitalization	
125 of the largest	Spain and Portugal	market capitalization	
100 of the largest	Brazil	market capitalization	BM&FBOVESPA IBrX100
	Region/sector	Based on	Index used for classification
100 of the largest	Central & Eastern Europe	market capitalization	
100 of the largest	China	market capitalization	
100 of the largest	Italy	market capitalization	
80 of the largest	Latin America	market capitalization	
100 of the largest	South Africa	market capitalization	FTSE/JSE 100

100 of the largest	Switzerland	market capitalization	SPI Large & MidCap SOCI
100 of the largest	Transport sector globally	market capitalization	
100 of the largest	Turkey	market capitalization	ISE 100
50 of the largest	Russia	market capitalization	RTS Index
30 of the largest	Ireland	market capitalization	

Source: CDP (2013).