Firm Competitiveness and the European Union Emissions Trading Scheme

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The World Bank
Europe and Central Asia Region
Energy Unit
October 2013
Abstract

The European Union Emissions Trading Scheme is the first international cap-and-trade program for carbon dioxide and the largest carbon pricing regime in the world. A significant concern over the Emissions Trading Scheme has been the potential impact on the competitiveness of industry. Using data on 5,873 firms in ten European countries during 2001–2009, this paper assesses the impact on three variables through which the effects on firm competitiveness may manifest—unit material costs, employment and revenue. The analysis focuses on the three most heavily-emitting industries under the program—power, cement, and iron and steel. Empirical results indicate that the Emissions Trading Scheme has had different impacts across these three sectors. Although no impacts are found on any of the three variables in the cement and iron and steel industries, a positive effect is found on both material costs and revenue in the power sector. The effect on material costs likely reflects fuel-switching to reduce carbon dioxide emissions, while that on revenue may be partly due to cost pass-through to consumers in a market that is less exposed to competition outside the European Union. Overall the findings do not substantiate concerns over carbon leakage, job loss or industry competitiveness during the study period.

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Firm Competitiveness and the European Union Emissions Trading Scheme

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Keywords: Cap and trade, EU emissions trading scheme, Firm competitiveness

JEL Classification: L38, L51, Q58

Sector Board: Energy and Mining

\textsuperscript{1} We thank Tarik Chfadi, Lauren Masatsugu, Derek Lougee and Gianni Parente for excellent research assistance. Financial Support from the World Bank Knowledge for Change Program is gratefully acknowledged. The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the International Bank for Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.

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1 Introduction

The European Union Emissions Trading Scheme (EU ETS) is the world’s first large implementation of a CO₂ cap-and-trade system. Launched in 2005, it forms the centerpiece of the EU’s climate policy to reduce greenhouse gas emissions by 20 percent below 1990 levels before 2020. Under the system, each EU member state sets an annual cap limiting total CO₂ emissions from electric utilities and energy-intensive industrial plants. The government then divides the cap into individual allowances to emit one ton of CO₂ and allocates them to participating firms. At the end of every compliance year, each firm must deduct enough allowances from its account to cover its emissions for that year. Firms can trade allowances among each other, purchasing extra allowances if they emitted more, selling or saving allowances if they emitted less. The EU’s trading scheme effectively puts a price on carbon emissions via the trading price for allowances. Today more than 12,000 power generators and heavy manufacturing units in 30 countries are covered by the system.

Emissions trading such as the EU ETS has gained popularity over the past two decades as a market-based policy instrument to minimize the costs of environmental regulation. Experience in the United States has shown that well-designed emissions trading programs can reduce policy costs by between 15 to 90 percent compared to traditional command-and-control programs (Schmalensee and Stavins, 2012; Carlson et al, 2000; Ellerman et al, 2000; Keohane, 2003). Although the cost-effectiveness of carbon trading is widely acknowledged, a major unresolved issue in the debate over EU ETS is whether it would impose an unsustainable burden on the industry.

The conventional wisdom is that environmental regulations even based on market-based approaches could divert productive investment (Rose, 1983) or reduce operating flexibility (Joshi et al., 1997) and therefore adversely affect firm productivity. More importantly, because the EU was the first to impose carbon regulation, there is concern that such unilateral action would hinder the competitiveness of EU firms in the global market. Proponents of this view hold that stringent environmental regulations could actually enhance productivity growth by stimulating innovation and efficiency (i.e., the Porter hypothesis, Porter (1991)) and therefore will have a

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5 Banking of excess allowances for future years is allowed within the first compliance period (phase I of EU ETS during 2005-2007), and is mandatory after 2012.
positive impact on the competitiveness of the firm. Another concern is that emission-intensive firms in the EU could relocate to regions with no or lesser carbon restrictions. The economic relocation would be accompanied by loss of jobs and market shares, as well as carbon leakage whereby emission reductions in the EU could be more than offset by increases elsewhere.

Two strands of the literature have addressed the above questions on competitiveness and carbon leakage. The first are *ex ante* studies to simulate the potential carbon leakage in a range of energy-intensive manufacturing sectors. Based on assumptions on CO₂ prices, demand elasticities and trade exposure, these studies project leakage rates ranging from very low to significant at 30 percent or more (Ponssard and Walker, 2008; Demailly and Quiron, 2008; Reinaud, 2008; etc.). For example, Demailly and Quirion (2008) examine the impact on the cement industry under a euro 20 per ton CO₂ price. They found that the leakage rates range from 0.5 to 25 percent among EU-27 countries with a mean value of 6 percent.

The literature on *ex post* empirical analysis is relatively thin. Abrell et al. (2011) assess the impact of the EU ETS on firm competitiveness based on data of 2,000 European firms during 2005-2008. They find no statistically significant impact of the EU ETS on firm value added, profit margin or employment. Anger and Oberndorfer (2008) examine the impact of the EU ETS on firm revenue and employment based on a sample of German firms over the period of 2005-2006. Their analysis suggests that the initial allocation of allowances did not affect revenue or employment and therefore the impact of carbon regulation on firm competitiveness is likely to be modest. Jaraite and Maria (2011) investigate the effect of Phase 1 (2005-2007) EU ETS on productivity growth of the power generating sector using macro-level data of 24 European countries during 1996-2007. They find that carbon pricing had a positive impact on technological change. Overall, the existing empirical literature seems to find little evidence to support the hypothesis that EU ETS would have a large adverse impact on competitiveness.

In this paper, we measure the effect of the EU ETS on firm unit material cost, employment and turnover based on a panel of 5,873 firms in the electric power, cement and steel industry from 10 European countries⁶ during 2005-2009. The power sector is the most heavily affected by the carbon regulation. During the sample period, the sector was short by around 440 million

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⁶ Austria, Belgium, Czech Republic, France, Germany, Great Britain, Italy, Netherlands, Poland and Spain.
allowances and was a net buyer of allowances within the EU. The cement and iron industries are vulnerable to carbon leakage as both are tradable industries and cannot pass through increased energy costs into product prices without incurring a loss of market share. All together, the three (power, cement, iron and steel) sectors account for 86.76 percent of carbon emissions in the EU and constitute 86.98 percent of total demand and 85.33 percent of total supply of carbon allowances.

We match firm financial data from the AMADEUS database maintained by Bureau van Dijk with emission transaction records reported in the Community Independent Transaction Log (CITL) run by the European Commission. We then use participant and nonparticipant firms of similar sizes within the same industry category to construct the control and treatment groups. Using a fixed effects specification, we estimate the impact of carbon trading, as well as the initial allocation of allowances on firm competitiveness. Our analysis differs from previous research in two ways. First, unlike the study of Abrell et al. (2011) that uses firms from different (non-ETS) industries as the counterfactual, we compare performance of regulated and unregulated firms within the same industry. In doing so, we avoid potential bias by omitted variables characterizing time-variant differences among industries. Second, our study covers more industries, more countries and a longer period of the trading program than other studies. Therefore, our paper provides additional evidence on the impacts of the carbon regulation.

The results from this study suggest that the EU ETS had different impacts across sectors. Our results show that the program may have resulted in higher material costs of the power industry on average by about 5 percent during 2005-2007 (Phase 1) and 8 percent during 2008-2009 (Phase 2). Since power generation requires fuel input, rising material costs may suggest that firms choose to substitute low-cost coal with more expensive fuel such as natural gas to mitigate emissions. In addition, the turnover of the power companies on average increased by 30 percent in Phase 2. This could imply that fossil-fuel power generation companies have passed through the carbon price to ratepayers, resulting in higher electricity prices and higher revenue. On the other hand, the trading scheme seems to have had no statistically significant impacts on any of the three variables in the cement and iron and steel sectors. The differences between ETS

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7 These numbers are determined using the sample of 10 countries used in this study due to the need to identify power plants from the combustion sector.
and non-ETS firms in these two industries in material costs, employment and turnover are statistically insignificant. This finding suggests that there is likely to be no shift of production elsewhere. The free allocation of emission allowances gave firms a source of revenue and this could partially explain the limited impact of EU ETS so far.

The remainder of the paper is organized in the following. Section 2 provides a background of EU ETS. Section 3 describes the data. Section 4 discusses the empirical strategy. Section 5 presents the results and Section 6 concludes.

2 The EU Emissions Trading Scheme

The EU ETS was approved by the European Commission in 2003 and officially launched in 2005. It was set up with three phases. Phase 1, from 2005 through 2007, was intended as much to gain business buy-in and develop institutions as to achieve CO2 reductions. As a result, many regulated firms in the manufacturing sectors received more allowances than they subsequently needed to cover their emissions. Phase 2, which ran from 2008 to 2012, tightened the cap (6.5 percent below the 2005 emission levels). But again, the emerging evidence is that delivering the emission reductions required became easier and cheaper than expected, largely because of the economic recession. Phase 3, which will run from 2013 to 2020, will implement steeper emission cutbacks (the cap will decrease each year by 1.74 percent) and move from free allocation of allowances to auction.

During the first two phases, the trading scheme covers energy-related CO2 emissions\(^8\) from power and heat generation and nine energy-intensive industries, including cement, iron and steel, oil refineries, coke ovens, and industries producing glass, lime, bricks, ceramics, pulp, paper and board.\(^9\) However, not all firms in the regulated industries are obligated to participate in trading. A size threshold based on production capacity or output was used to determine the coverage within each sector. For example, participation of power utilities is limited to installations greater than 20 megawatts in capacity. For the cement industry, the threshold is 500 metric tons of production per day. This participation eligibility provides an opportunity to create treatment and control groups within the same industry.

\(^8\) With the exception of the Netherlands, which has opted in emissions of nitrous oxide.

\(^9\) Aviation is included in the trading scheme as from 2012. When the third trading period start, the scope of the ETS will be further extended to cover more sectors and additional greenhouse gases.
For each participating installation, an account is set up in its national emissions trading registry to record the issuance, transfer, cancellation, retirement and banking of allowances. All national registries are also connected to a central registry at the EU level—the Community Independent Transaction Log (CITL). The centralized registry tracks the ownership of allowances across the entire carbon market. Using information presented in CITL, we are able to identify participants and non-participants in the three trading sectors under study. We then choose firms that are similar in size (measured by turnover before the program) to form our treatment and control groups. More details on data construction are explained in the next section.

Another key element of EU ETS is the initial allocation of emission allowances. During the first two trading periods, the program gives national governments substantial discretion in determining the allocation and distribution of allowances across sectors, subject to general guidelines by the European commission. During 2005-2012, over 90 percent of the allowances were given out for free to trading sectors based on burden sharing obligations under the Kyoto Protocol, and individual installations’ historical emissions and projected abatement costs. Early evidence suggests that at the aggregate level power generation was the only sector receiving fewer allowances than verified emissions (Ellerman and Buchner, 2008). The power sector faced more stringent regulation because it is thought to have more low-cost abatement options and is less exposed to international competition.

Despite evidence of the over-allocation at the sector level, firms still have incentives to cut emissions since they can sell excess permits at the ongoing market price. Indeed, several studies suggest that CO₂ emissions dropped by around 3 percent relative to a baseline without ETS during the pilot phase (Ellerman and Buchner 2008; Ellerman, Convery and de Perthuis, 2010; Anderson and Dimaria, 2011), and the first two years of Phase II (Abrell et al., 2011). There are several ways through which power utilities and industries can mitigate emissions. These include switching to low-carbon fuels, optimizing production processes, and investing in more efficient equipment and low-carbon technologies.

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10For the third trading period beginning in 2013, there will no longer be any national allocation plans. Instead, the allocation will be determined directly at the EU level.
3 Data

The main data source of firm economic performance is the AMADEUS data set from 2001 to 2009. AMADEUS is a commercial database containing financial information for more than 11 million firms in 41 European countries. Each firm in the database includes a wide range of standardized financial statement information\(^{11}\) such as asset holdings, turnover, cost of employees, working capital and net income. The comprehensiveness of the data set allows us to control for a number of firm characteristics and examine the effect of program participation in a number of dimensions. In this paper, we focus on three industries (power, cement, and iron and steel) and investigate three different variables that reflect firm competitiveness - unit material cost (which is defined as the ratio of total material costs to turnover), number of employees, and turnover (revenue).

As discussed in section 2, the EU ETS covers installations in nine trading sectors (with specific size thresholds). To locate the participating firms, we first identify firms in the above three sectors in AMADEUS using NACE (revision 2, 4 digit class level) industry code\(^ {12}\). We then manually match the AMADEUS firms with those in CITL. One difficulty in matching these two databases is that although AMADEUS has a precise sectoral classification (a NACE code), CITL defines sectors based on "activities". For example, the combustion sector defined in CITL includes a number of industries that incur combustion processes, such as power generation, food processing, pharmaceutical, etc. In cases when sector classifications do not match, we use zip code, name of parent company, address and contact information to identify EU ETS firms.

We define program participation based on allowances submission – an installation is a participant if it surrenders a positive number of allowances in that year. Since a firm can have multiple installations and therefore several accounts in CITL, we sum across all the accounts matched with an AMADEUS firm to obtain firm-level allowance allocation and submission. We focus on ten large countries, Austria, Belgium, Czech Republic, France, Germany, Great Britain, Austria, Belgium, Czech Republic, France, Germany, Great Britain, Austria, Belgium, Czech Republic, France, Germany, Great Britain.

\(^{11}\) One potential problem of using financial statement information is the different closing dates of the accounting period. We define the observation as in year \(t\) if the accounting period ends on any date from April 1 in year \(t\) to March 1 in year \(t+1\).

\(^{12}\) We define the power generation industry as firms in NACE 35.11 – “Production of Electricity”; the cement industry as the combination of NACE 23.51 – “Manufacture of Cement” and NACE 23.52 – “Manufacture of Lime and Plaster”. There are multiple sub-sectors under the iron and steel industry with drastically different products and processes, for the purpose of this analysis we define iron and steel firms as those with NACE 24.10 – “Manufacture of Basic Iron and Steel and of Ferro-Alloys”.

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Italy, Netherlands, Poland and Spain. Table 1 lists the top 15 countries in recorded emissions in CITL. The ten countries covered in the analysis are among the biggest polluters. Table 2 shows the proportion of CITL installations that are matched – the ratio of matched firms and total firms in each CITL sector. Though the power sector has a low match ratio, most of the non-matched firms are identified as being in non-power sectors, therefore we believe that our control group will not contain ‘treated’ firms.

### Table 1: Top 15 Polluting Countries

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Verified Emissions (million tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Germany*</td>
<td>466</td>
</tr>
<tr>
<td>2</td>
<td>Great Britain*</td>
<td>247</td>
</tr>
<tr>
<td>3</td>
<td>Italy*</td>
<td>213</td>
</tr>
<tr>
<td>4</td>
<td>Poland*</td>
<td>203</td>
</tr>
<tr>
<td>5</td>
<td>Spain*</td>
<td>162</td>
</tr>
<tr>
<td>6</td>
<td>France*</td>
<td>122</td>
</tr>
<tr>
<td>7</td>
<td>Netherlands*</td>
<td>81</td>
</tr>
<tr>
<td>8</td>
<td>Czech Republic*</td>
<td>80.6</td>
</tr>
<tr>
<td>9</td>
<td>Greece</td>
<td>67.9</td>
</tr>
<tr>
<td>10</td>
<td>Belgium*</td>
<td>52.5</td>
</tr>
<tr>
<td>11</td>
<td>Finland</td>
<td>38.7</td>
</tr>
<tr>
<td>12</td>
<td>Romania</td>
<td>38.3</td>
</tr>
<tr>
<td>13</td>
<td>Austria*</td>
<td>31.3</td>
</tr>
<tr>
<td>14</td>
<td>Portugal</td>
<td>30.5</td>
</tr>
<tr>
<td>15</td>
<td>Denmark</td>
<td>27.9</td>
</tr>
</tbody>
</table>

Note: The ‘verified emissions’ is a simple time average of the total verified emissions of all installations on the CITL record. Starred countries indicate the ones in our sample. The names and addresses of Greek firms in the AMADEUS database did not transcript properly so we did not try to match these installations and their respective firms. * indicates countries that are covered in the study.
Table 2: CITL - AMADEUS Matching

<table>
<thead>
<tr>
<th>Country</th>
<th>Matching Proportion (%)</th>
<th>Power*</th>
<th>Cement</th>
<th>Iron#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td></td>
<td>0.289</td>
<td>0.837</td>
<td>0.957</td>
</tr>
<tr>
<td>Great Britain</td>
<td></td>
<td>0.191</td>
<td>0.538</td>
<td>1.000</td>
</tr>
<tr>
<td>Italy</td>
<td></td>
<td>0.026</td>
<td>0.836</td>
<td>0.913</td>
</tr>
<tr>
<td>Poland</td>
<td></td>
<td>0.055</td>
<td>0.708</td>
<td>1.000</td>
</tr>
<tr>
<td>Spain</td>
<td></td>
<td>0.345</td>
<td>0.879</td>
<td>0.929</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td>0.196</td>
<td>0.980</td>
<td>0.808</td>
</tr>
<tr>
<td>Netherlands</td>
<td></td>
<td>0.154</td>
<td>^</td>
<td></td>
</tr>
<tr>
<td>Czech Republic</td>
<td></td>
<td>0.099</td>
<td>0.818</td>
<td>1.000</td>
</tr>
<tr>
<td>Belgium</td>
<td></td>
<td>0.202</td>
<td>0.545</td>
<td>0.963</td>
</tr>
<tr>
<td>Austria</td>
<td></td>
<td>0.260</td>
<td>0.750</td>
<td>^</td>
</tr>
</tbody>
</table>

Note: *: Since the matching proportions are based on CITL 9 sectors, the power industry is just a small part of the combustion sector therefore we have a low probability of matching for power, though we suspect that the non-matched ones do not belong to the power sector.

^: We are not able to match any of the six cement CITL installations in Netherlands, where five of the installations belong to the same firm. Therefore, we do not include any cement firms in Netherlands in our analysis. Similarly for iron industry, we are not able to match the one CITL installation for Austria and we drop all Austrian firms in iron and steel industry.

#: Due to a broader classification of the CITL sectors, we conduct our matching by including all industries under “Manufacture of Basic Metals”, which may include manufacture of tubes, pipes, or other products of first processing of steel, but we only isolate firms that are in the primary iron and steel industry class (24.10). Thus we have dropped two Dutch installations, though they are matched, they do not belong to the primary industry class that we are focusing on.

Table 3 presents the summary statistics for both participating and non-participating firms by sector. As we can see from the last column, participants generally are bigger – they incur higher material and labor costs, and also have larger turnovers. This is not surprising given that only large emitters are regulated by EU ETS. However, the difference in size between participating and non-participating firms does impose a difficulty in estimating the causal effect (see more discussion in the next section). In order to create a robust control group to isolate the size effect we use the pre-program year in 2004 to choose non-participant firms that are ‘close enough’ to EU ETS firms. Specifically, we choose non-participant firms who have their 2004 turnover falling between the 25% and the 75% percentiles of the distribution of the turnover of the participant firms as the control group. Figures 1-3 illustrate the trend in unit material cost of participating and non-participant firms. For all the three sectors, the two groups share similar
trends before the program started in 2005. We plot trends for the other two dependent variables of interest and the pre-program trends also look similar.

Table 3 Summary Statistics by Sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Participants Mean</th>
<th>Participants N</th>
<th>Non-participants Mean</th>
<th>Non-participants N</th>
<th>Difference Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POWER GENERATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material cost</td>
<td>116399.5</td>
<td>1780</td>
<td>23962</td>
<td>2216</td>
<td>92178.7</td>
</tr>
<tr>
<td>(257650.6)</td>
<td></td>
<td></td>
<td>(44261.5)</td>
<td></td>
<td>(6194.2)</td>
</tr>
<tr>
<td>Unit material cost</td>
<td>0.59</td>
<td>1836</td>
<td>0.48</td>
<td>2189</td>
<td>0.11</td>
</tr>
<tr>
<td>(0.23)</td>
<td></td>
<td></td>
<td>(0.29)</td>
<td></td>
<td>(0.01)</td>
</tr>
<tr>
<td>Turnover</td>
<td>96664.6</td>
<td>2447</td>
<td>41877.4</td>
<td>2954</td>
<td>54098.4</td>
</tr>
<tr>
<td>(175802.3)</td>
<td></td>
<td></td>
<td>(66538.0)</td>
<td></td>
<td>(3772.2)</td>
</tr>
<tr>
<td>Number of employees</td>
<td>400</td>
<td>1615</td>
<td>105</td>
<td>1925</td>
<td>299</td>
</tr>
<tr>
<td>(739)</td>
<td></td>
<td></td>
<td>(199)</td>
<td></td>
<td>(19)</td>
</tr>
<tr>
<td><strong>CEMENT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material cost</td>
<td>86427.6</td>
<td>694</td>
<td>29922</td>
<td>466</td>
<td>55880.7</td>
</tr>
<tr>
<td>(155944.9)</td>
<td></td>
<td></td>
<td>(33863.5)</td>
<td></td>
<td>(6128.8)</td>
</tr>
<tr>
<td>Unit material cost</td>
<td>0.33</td>
<td>732</td>
<td>0.49</td>
<td>464</td>
<td>-0.17</td>
</tr>
<tr>
<td>(0.13)</td>
<td></td>
<td></td>
<td>(0.17)</td>
<td></td>
<td>(0.01)</td>
</tr>
<tr>
<td>Turnover</td>
<td>252651.7</td>
<td>848</td>
<td>63294</td>
<td>558</td>
<td>189595.1</td>
</tr>
<tr>
<td>(457188.5)</td>
<td></td>
<td></td>
<td>(75279.7)</td>
<td></td>
<td>(16313.3)</td>
</tr>
<tr>
<td>Number of employees</td>
<td>526</td>
<td>823</td>
<td>145</td>
<td>519</td>
<td>390</td>
</tr>
<tr>
<td>(1172)</td>
<td></td>
<td></td>
<td>(151)</td>
<td></td>
<td>(42)</td>
</tr>
<tr>
<td><strong>IRON AND STEEL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material cost</td>
<td>325580.0</td>
<td>590</td>
<td>235068.3</td>
<td>408</td>
<td>90797.0</td>
</tr>
<tr>
<td>(365430.2)</td>
<td></td>
<td></td>
<td>(213408.6)</td>
<td></td>
<td>(17841.2)</td>
</tr>
<tr>
<td>Unit material cost</td>
<td>0.62</td>
<td>643</td>
<td>0.68</td>
<td>406</td>
<td>0.06</td>
</tr>
<tr>
<td>(0.16)</td>
<td></td>
<td></td>
<td>(0.15)</td>
<td></td>
<td>(0.01)</td>
</tr>
<tr>
<td>Turnover</td>
<td>467611.6</td>
<td>617</td>
<td>305319.5</td>
<td>489</td>
<td>160209.6</td>
</tr>
<tr>
<td>(513468.6)</td>
<td></td>
<td></td>
<td>(243698.7)</td>
<td></td>
<td>(22978.4)</td>
</tr>
<tr>
<td>Number of employees</td>
<td>935</td>
<td>561</td>
<td>509</td>
<td>444</td>
<td>424</td>
</tr>
<tr>
<td>(1116)</td>
<td></td>
<td></td>
<td>(541)</td>
<td></td>
<td>(54)</td>
</tr>
</tbody>
</table>

Note: For the first two columns the standard deviations are recorded in respective parentheses, while the standard errors are recorded in the last ‘difference’ column. The difference column also controls for year fixed effects. \( N \) denotes number of observations.
Figure 1: Unit Material Cost Trend for the Power Generation Industry

Figure 2: Unit Material Cost Trend for the Cement Industry

Figure 3: Unit Material Cost Trend for the Iron and Steel Industry
4 Empirical Method

The goal of our empirical analysis is to examine the effect of the EU ETS program on firm competitiveness. The key to estimating the treatment effect is to construct the counterfactual outcome for program participants in the absence of the program. If program participants were chosen randomly, one could just compare the outcomes from the participants and non-participants to estimate the treatment effect during the program period. However, the program requires an industrial installation in nine industry sectors to participate only if the capacity or thermal usage of the installation exceeds certain levels. Without randomized program assignment, we turn to difference-in-differences (DD) estimation by taking advantage of the panel nature of our data. By using non-participants as the control group, the DD method compares the differences in outcomes for participants (the treatment group) before and after the intervention with the same differences for the control group. By focusing on changes instead of levels, the method controls for time-invariant characteristics that could be correlated with the outcome variables. By comparing changes in the two groups, we can control for time trends that were constant across the two groups.

We specify the DD method through a two-way fixed effects linear regression model:

$$y_{it} = \alpha d_{it} + x_{it}'\beta + f_i + d_{ct} + u_{it}$$  

(1)

where $i$ indexes a firm and $t$ indexes year. $y_{it}$ is the logarithm of the outcome variable that we are interested in including unit material cost, number of employee, as well as turnover. $d_{it}$ is a dummy variable which is one if firm $i$ is participating in the program at time $t$. The model also controls for observed time-varying covariates, $x_{it}$, a full set of firm effect, $f_i$, and a full set of country-year fixed effect, $d_{ct}$, where $c$ indexes the host country of firm $i$. The firm fixed effects control for time-invariant firm-level factors that affect outcome variable, while the country-year fixed effects control for country-specific time trend such as macroeconomic conditions. $u_{it}$ is the idiosyncratic error term. In this setup, the OLS estimate $\hat{\alpha}$ can be used to estimate the average treatment effect. 13

Although the model includes a full set of firm fixed effects $f_i$, and country-year fixed effects $d_{ct}$, the unbiasedness of $\hat{\alpha}$ as an estimator of the average treatment effect still relies on the

13 As the equation takes the semi-logarithmic functional form and $d_{it}$ is a dummy variable, a consistent and unbiased estimator for the percentage impact of the dummy regressor on the leveled dependent variable is $\exp(\hat{\alpha} - \text{var}(\hat{\alpha}/2))-1$. 

12
following two critical assumptions. The first one is that the trends in the dependent variable over
time captured by $d_{it}$ should be the same across the treatment and control groups. This assumption
could be violated if changes in conditions faced by both groups (such as macroeconomic
conditions) have different effects on the outcome variables across the two groups. Given the
systematic difference in firm size between the treatment and control groups, it may be of
particular concern if changes in outcome variables would be the same in the absence of the
program during the program period. Because we have more than two years of data before the
program started, we can see whether the pre-intervention time trends are the same for the control
and treatment groups. If they are the same before the program as is the case in our context, it will
lend some support for the assumption that they are the same after the program started.

The second assumption is that the start of the EU ETS program is mean independent of the
error term. This assumption could be violated if the EU started the program in response to time-
varying factors that affect outcome variables such as employment that are specific to the
treatment group. However, this violation is unlikely to happen given that the EU ETS was a way
to fulfill EU obligations from the Kyoto protocol and to combat climate change.

5 Empirical Results

5.1 Power Plants

In this section, we present results for power plants. We present results for four specifications
for each of the three regressions on employment, material costs, and turnover. The first
regression is from OLS without controlling for firm fixed effects and time effects. The second
regression includes firm fixed effects while the third regression has both firm fixed effects and
country-year fixed effects. The fourth regression adds interaction terms between the program
participation dummy and permit allocation and usage variables.

Table 4 shows parameter estimates and clustered standard errors (at the firm level) for the
first regression where the dependent variable is the number of employees (in log). The results
from the first two specifications suggest that the program increased employment among
participants in both phases. However, the parameter estimates for the third regressions suggest
that the program decreased employment in power plants under the program by about 3 percent in
the first phase and 2 percent in the second phase.
Table 4: Results on Employment for Power Plants

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<td>0.0792*</td>
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<td>(4.01)</td>
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<td>-0.326</td>
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<td>(2.80)</td>
<td>(1.96)</td>
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<td>(-0.82)</td>
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<td></td>
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Note: Dependent variable is the logarithm of number of employees. Standard errors are clustered at the firm level and t statistics are shown in the respective parentheses. *, **, and *** indicate significance at the 10, 5, and 1 percent levels.

Nevertheless, both effects are not statistically significantly different from zero. The last specification interacts the program participation dummy variables with allowances surrendered and allocated. The results suggest that there is no heterogeneous effect across firms with different levels of allowance usage and allocation during the first phase. Under the second phase, a larger allowance usage is associated with a larger employment while a larger allocation is associated with fewer employees. The number of allowance surrendered is likely affected by unobserved idiosyncratic factors at the plant level that affect production and hence emissions. So we abstain from interpreting these coefficients as causal effects.

Table 5 presents estimated effects on material costs, a large proportion of which is fuel costs. The first three specifications all suggest a positive impact on material costs from program participation. The third specification with firm fixed effects and country-year fixed effects provides the smallest estimates: about 5 percent increase in phase one and 8 percent increase in phase two. The increase in material costs could reflect fuel switching (e.g., coal to natural gas) in
order to reduce carbon emissions. The fourth specification with interactions shows that the increase in material costs is larger among firms with a larger allocation of permits.

Table 5: Results on Unit Material Cost for Power Plants

<table>
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<th>(4)</th>
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<tr>
<td>Phase 1 Participation</td>
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<td>0.0693***</td>
<td>0.0479***</td>
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<td>(7.88)</td>
<td>(6.92)</td>
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<td>0.0895***</td>
<td>0.0820***</td>
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<td>(5.92)</td>
<td>(6.80)</td>
<td>(4.41)</td>
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<td>(-0.85)</td>
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<td>0.0191*</td>
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<td>3712</td>
<td>3712</td>
<td>3712</td>
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<td>Adjusted $R^2$</td>
<td>0.036</td>
<td>0.042</td>
<td>0.101</td>
<td>0.107</td>
</tr>
</tbody>
</table>

Note: Dependent variable is the unit material cost, defined as the ratio of total material cost to operating revenue. Standard errors are clustered at the firm level and $t$ statistics are shown in the respective parentheses. *, **, and *** indicate significance at the 10, 5, and 1 percent levels.

The results for firm turnover are shown in table 6. The first two specifications suggest that the program increased turnover in both phases while the third specification with firm fixed effects and country-year fixed effects shows no statistically significant effect on average in the first phase and an almost 30 percent increase in the second phase. The increase in turnover could come from an increase in output or in price or in both components. Intuitively, an increase in material costs could lead to an increase in electricity prices. Since electricity demand is highly inelastic in the short-run, the price increase could translate into an increase in turnover. The fourth specification with interaction terms suggests that the increase in turnover is larger among firms with a larger usage in both phases. On the other hand, a larger allocation of allowances is associated with a smaller turnover in the second phase. Both findings could reflect utilities passing the cost (from compliance) to consumers.
Our analysis shows that the EU ETS in the first two phases had no statistically significant impact on the number of employees among power plants under the program. Given that electricity markets are mostly national and electricity demand is relatively inelastic, the program is unlikely to hinder the competitiveness of the power plants in the form of reduced demand. Nevertheless, the program increased material costs, most likely due to fuel cost increases from compliance. In addition, the regressions also show a positive impact on firm turnover. Whether the increase in turnover will dominate the increase in material costs and other costs, i.e., the impact of the program on profit, is left for future research.

5.2 Cement

Tables 7-9 present estimation results on employment, material costs and turnover for the cement industry. The model specification in each column is the same as those in the previous section. The fixed-effects model with firm and country-year dummies is again our preferred specification.
In Table 7, the pooled regression in column (1) shows that participation in the first two periods of the trading is associated with a strong and significant increase in employment. These higher estimates are likely driven by the systematic difference between regulated and unregulated firms - EU ETS firms are larger with higher production capacity. Once controlling for the fixed firm-level differences (column (2)), the parameter estimates on program participation become much smaller and are no longer statistically significant. Column (3) considers the possible heterogeneity in the time trends among participating nations. The results indicate that employment reduced by 2 and 4 percent, respectively, during the first and second phase of the program. However, these effects are statistically insignificant. Column (4) shows that controlling for the allocation and surrender of allowances does not change the results.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
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<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase 1 Participation</strong></td>
<td>0.420***</td>
<td>0.0657</td>
<td>-0.0220</td>
<td>-0.0761</td>
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<td></td>
<td>(3.37)</td>
<td>(1.28)</td>
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<td>(-0.29)</td>
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<td><strong>Phase 2 Participation</strong></td>
<td>0.357***</td>
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<td>-0.0423</td>
<td>-0.548</td>
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<td></td>
<td>(2.84)</td>
<td>(0.93)</td>
<td>(-0.38)</td>
<td>(-1.55)</td>
</tr>
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<td><strong>Phase 1× Log(Surrendered)</strong></td>
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<td>(1.83)</td>
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<td>(0.73)</td>
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<td>-0.0585</td>
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<tr>
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<td>(-1.61)</td>
<td></td>
</tr>
<tr>
<td><strong>Phase 2×Log(Allocated)</strong></td>
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<td></td>
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<td>(-0.32)</td>
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<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Country-by-Year Fixed Effects</strong></td>
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<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<td><strong>Observations</strong></td>
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<td>1205</td>
<td>1205</td>
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<tr>
<td><strong>Adjusted $R^2$</strong></td>
<td>0.017</td>
<td>0.004</td>
<td>0.034</td>
<td>0.062</td>
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</tbody>
</table>

Note: Dependent variable is the logarithm of number of employees. Standard errors are clustered at the firm level and $t$ statistics are shown in the respective parentheses. *, **, and *** indicate significance at the 10, 5, and 1 percent levels.

Table 8 presents the estimation results on material costs. The OLS model suggests that EU ETS firms have lower material costs by 9-10 percent compared to their unregulated counterparts. The difference could be explained by the fact that larger firms are more efficient at production due to economies of scale. In contrast to the OLS results, the negative correlation disappears in
fixed effects models. Based on our preferred estimator in column (3), firm material costs slightly
decline due to participation in the carbon trading. However, this effect is not significant at any
reasonable level of confidence. Column (4) shows that a one percent increase in the usage of
allowances in phase 1 is associated with a 0.7 percent increase in the material costs. As explained
earlier, because allowances and other material inputs are both likely to be correlated with
unobserved exogenous shocks, we do not interpret the result as a causal effect.

Table 8 Results on Unit Material Cost for Cement

<table>
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<th>(2)</th>
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</tr>
</thead>
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<tr>
<td>Phase 1 Participation</td>
<td>-0.0997***</td>
<td>-0.00232</td>
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<td></td>
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<td>Phase 2 Participation</td>
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<td>(-4.65)</td>
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<td>(-0.79)</td>
<td>(-1.61)</td>
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<td>Phase 1×Log(Surrendered)</td>
<td></td>
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<td>0.00665*</td>
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<tr>
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<td></td>
<td></td>
<td>(1.76)</td>
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<td>(-0.77)</td>
<td></td>
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<td>Phase 2×Log(Allocated)</td>
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<td></td>
<td>-0.0183</td>
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<td>Adjusted $R^2$</td>
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Note: Dependent variable is the unit material cost, defined as the ratio of total material cost to operating
revenue. Standard errors are clustered at the firm level and t statistics are shown in the respective parentheses.
*, **, and *** indicate significance at the 10, 5, and 1 percent levels.

Table 9 summarizes regression results on the determinants of firm turnover. The estimated
parameters of the OLS and firm fixed effects models in columns (1) and (2) suggest that
participating in EU ETS is associated with a large and statistically significant (in the case of
fixed-effects model) increase in turnover. We suspect this seemingly counterintuitive result could
be explained by country-specific shocks contemporaneous with the implementation of EU ETS.
For example, some countries may have facilitated state aid to balance the impact of the carbon
regulation. Indeed, once we control for country-year fixed effects as in our preferred
specification in column (3), the correlation between program participation and firm turnover
becomes negative and statistically insignificant from zero. The Column (4) shows that higher consumption of allowances in phase 1 is associated with a larger amount of turnover. This correlation is more likely driven by factors such as demand shocks that simultaneously influence emission and outputs.

Table 9: Results on Turnover for Cement

<table>
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<td>(1.63)</td>
<td>(4.23)</td>
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<td>Phase 1×Log(Surrendered)</td>
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<td>0.0949*</td>
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Note: Dependent variable is the logarithm of operating revenue. Standard errors are clustered at the firm level and t statistics are shown in the respective parentheses. *, **, and *** indicate significance at the 10, 5, and 1 percent levels.

Overall, the above results suggest that the EU ETS is neither detrimental nor profitable for the cement industry. There is also little evidence to support carbon leakage.

5.3 Iron and Steel

Lastly, we run similar regressions for firms in the iron and steel industry, and the results are in tables 10-12. In table 10, column (1) shows that the two phases of the EU ETS led to a statistically significant increase in employment, which can be seen from the summary statistics in table 3. As argued above, this result is not valid if there are other unobserved effects that may be correlated with the participation as well as the dependent variable (employment). Columns (2) and (3) therefore control for firm fixed effects and country-by-year fixed effects. We can see that
in column (3), after controlling for unobserved time-invariant firm-specific effects and time-variant country-specific effects, the EU ETS participation in Phase 2 has no effect on employment, though Phase 1 participation shows a non-significant 10 percent decrease. Most of the effects in column (1) are absorbed into the firm fixed effects. Column (4) controls for allowances allocated and surrendered. We can see that there is a positive effect of surrendered permits on employment of Phase 1 participating firms, though that may be caused by the positive production shocks that increase both labor and pollution.

Table 10 Results on Employment for Iron and Steel

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 Participation</td>
<td>0.631***</td>
<td>0.0552</td>
<td>-0.102</td>
<td>-1.012**</td>
</tr>
<tr>
<td></td>
<td>(3.38)</td>
<td>(0.42)</td>
<td>(-0.60)</td>
<td>(-2.05)</td>
</tr>
<tr>
<td>Phase 2 Participation</td>
<td>0.441**</td>
<td>0.146</td>
<td>0.00211</td>
<td>-0.756</td>
</tr>
<tr>
<td></td>
<td>(2.28)</td>
<td>(1.29)</td>
<td>(0.01)</td>
<td>(-1.08)</td>
</tr>
<tr>
<td>Phase 1× Log(Surrendered)</td>
<td>0.0803*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.70)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 2×Log(Surrendered)</td>
<td>-0.00854</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 1×Log(Allocated)</td>
<td>0.000179</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 2×Log(Allocated)</td>
<td>0.0743</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.79)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Plant Fixed Effects  | No       | Yes     | Yes      | Yes      |
Country-by-Year Fixed Effects  | No       | No      | Yes      | Yes      |
Observations            | 902      | 902     | 902      | 902      |
Adjusted $R^2$          | 0.029    | 0.002   | 0.003    | 0.002    |

Note: Dependent variable is the logarithm of number of employees. Standard errors are clustered at the firm level and t statistics are shown in the respective parentheses. *, **, and *** indicate significance at the 10, 5, and 1 percent levels.

Table 11 tabulates the results for unit material cost. The OLS result in column (1) shows that there are no statistically significant relationship between EU ETS participation and unit material cost. The fixed effects model in column (2) implies the Phase 1 of EU ETS increases the unit material cost of steel plants by about 4.3 percent. However, after controlling for possible policy responses by participating countries, the effect decreases to around 2.5 percent and it is no longer statistically significant. In both cases, Phase 1 appears to have no impact on the iron and steel plants— before and after controlling for the country-by-year dummies, Phase 1 participation
increases the unit material cost by 3.3 percent and decreases that by 0.8 percent respectively, and both effects do not appear to be statistically significant too. From column (4) it appears that there is correlation between unit material cost, Phase 2 participation and allocated permits, but we are being cautious here on whether these results are causal for reasons explained earlier.

Table 11 Results on Unit Material Cost for Iron and Steel

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 Participation</td>
<td>-0.0188</td>
<td>0.0134</td>
<td>-0.00786</td>
<td>0.0335</td>
</tr>
<tr>
<td></td>
<td>(-1.04)</td>
<td>(1.27)</td>
<td>(-0.53)</td>
<td>(0.54)</td>
</tr>
<tr>
<td>Phase 2 Participation</td>
<td>0.0192</td>
<td>0.0430***</td>
<td>0.0250</td>
<td>-0.0857</td>
</tr>
<tr>
<td></td>
<td>(1.07)</td>
<td>(3.37)</td>
<td>(0.83)</td>
<td>(-0.98)</td>
</tr>
<tr>
<td>Phase 1× Log(Surrendered)</td>
<td></td>
<td></td>
<td></td>
<td>-0.00125</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-0.20)</td>
</tr>
<tr>
<td>Phase 2× Log(Surrendered)</td>
<td></td>
<td></td>
<td></td>
<td>-0.0356</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-1.37)</td>
</tr>
<tr>
<td>Phase 1× Log(Allocated)</td>
<td></td>
<td></td>
<td></td>
<td>-0.00215</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-0.35)</td>
</tr>
<tr>
<td>Phase 2× Log(Allocated)</td>
<td></td>
<td></td>
<td></td>
<td>0.0438</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(1.54)</td>
</tr>
<tr>
<td>Plant Fixed Effects</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Country-by-Year Fixed Effects</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>950</td>
<td>950</td>
<td>950</td>
<td>950</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.003</td>
<td>0.033</td>
<td>0.080</td>
<td>0.096</td>
</tr>
</tbody>
</table>

Note: Dependent variable is the unit material cost, defined as the ratio of total material cost to operating revenue. Standard errors are clustered at the firm level and t statistics are shown in the respective parentheses. *, **, and *** indicate significance at the 10, 5, and 1 percent levels.

Finally table 12 looks at the effect of EU ETS on firm operating revenue. Both the OLS results and the fixed effects results show a positive and statistically significant relationship between EU ETS and firms’ turnover. These results suggest that Phase 1 and Phase 2 of EU ETS increase the firms’ sales by 48-53% and 24-40% respectively. While it seems unintuitive that a cap-and-trade program (which increases their costs somehow) will increase revenue, this correlation can be explained by some revenue-improving country policies that are correlated with the program timing that also affects the participants. After controlling for time-varying country-specific factors in column (3), the effects significantly drop and become insignificantly different from zero.
Table 12 Results on Turnover for Iron and Steel

<table>
<thead>
<tr>
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<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 Participation</td>
<td>0.533***</td>
<td>0.483***</td>
<td>-0.0484</td>
<td>0.172</td>
</tr>
<tr>
<td></td>
<td>(3.44)</td>
<td>(4.39)</td>
<td>(-0.30)</td>
<td>(0.41)</td>
</tr>
<tr>
<td>Phase 2 Participation</td>
<td>0.239*</td>
<td>0.404***</td>
<td>0.117</td>
<td>0.592</td>
</tr>
<tr>
<td></td>
<td>(1.70)</td>
<td>(3.65)</td>
<td>(0.51)</td>
<td>(1.01)</td>
</tr>
<tr>
<td>Phase 1 × Log(Surrendered)</td>
<td></td>
<td></td>
<td>-0.00092</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-0.02)</td>
<td></td>
</tr>
<tr>
<td>Phase 2 × Log(Surrendered)</td>
<td></td>
<td></td>
<td>0.0498</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.46)</td>
<td></td>
</tr>
<tr>
<td>Phase 1 × Log(Allocated)</td>
<td></td>
<td></td>
<td>-0.0195</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-0.46)</td>
<td></td>
</tr>
<tr>
<td>Phase 2 × Log(Allocated)</td>
<td></td>
<td></td>
<td>-0.0897</td>
<td></td>
</tr>
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<td></td>
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<td>(-0.86)</td>
<td></td>
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<td>Plant Fixed Effects</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Country-by-Year Fixed Effects</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>987</td>
<td>987</td>
<td>987</td>
<td>987</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.022</td>
<td>0.054</td>
<td>0.281</td>
<td>0.279</td>
</tr>
</tbody>
</table>

Note: Dependent variable is the logarithm of operating revenue. Standard errors are clustered at the firm level and t statistics are shown in the respective parentheses. *, **, and *** indicate significance at the 10, 5, and 1 percent levels.

6 Conclusion

The EU ETS is the first international cap-and-trade program for CO$_2$ and the largest environmental pricing regime in the world (European Commission 2012). Covering more than 12,000 power stations and industrial plants in 30 countries, it will finish its second phase and expand to more industrial sectors such as petrochemicals in 2013. Understanding the impacts of such a large-scale environmental intervention on firms is important not only because it is a critical step to examine the cost-effectiveness of the program itself, but it can also provide useful lessons for other countries and regions that are contemplating cap-and-trade programs, such as China and India.

While there exists a large literature on the U.S. SO$_2$ allowance trading program, the world’s first (and now virtually collapsed) large-scale cap-and-trade program, empirical studies on the EU ETS program are much scarcer. Our paper adds to this literature by investigating the impacts
of EU ETS on material costs, employment and turnover for three main sectors: electric power, cement, iron and steel.

The program impacts on firms by the EU ETS can be at best described as limited and isolated among the three sectors analyzed during the first phase (2005-2007) and the first part of the second phase (2008-2009). Our preliminary analysis showed a statistically significant effect only on material costs and turnover among power plants and none were detected on any of the three variables of interests in cement, or iron and steel firms. We conjecture that the increase in material costs among power plants was due to fuel switching. Fuel costs account for a major portion of material costs especially among fossil fuel based power plants. The program could have induced them to switch from coal to natural gas in order to reduce CO₂ emissions. The increase in turnover in the second phase could partly reflect the cost pass-through to consumers in a market less exposed to competition outside the EU. Our finding of no impacts for cement and iron and steel sectors suggests that concerns over carbon leakage, job loss and industry competitiveness are not substantiated at least during the study period. Lastly, the varying impacts underscore the validity of the sector-by-sector empirical approach.

It is important to note that these findings should be viewed within the context of the specific program period analyzed. As discussed in our introduction, the first phase of the EU ETS is a trial phase where an abundance of allowances was allocated. Although the second phase aimed to reduce the CO₂ emissions by 6.5 percent below the 2005 level, the economic recession made the goal easier to achieve. In the future, we plan to extend the research in at least the following two directions. First, while we have analyzed material costs, employment and turnover so far, we have not examined the impact on firm profit yet. Second, we plan to include data from 2010 to 2012 in our analysis so that we can get a more complete picture of the impacts of the second phase of the program.
References


