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Abstract

We investigate the effect of cap-and-trade regulation on firm profits by performing an event study of the EU CO_2 price crash. We examine returns for 124 carbon-intensive stocks and over 400 additional stocks, all from the broad EUROSTOXX index. Despite a reduction in environmental costs, we find that stocks fell for firms in carbon-intensive industries. We find similar effects for firms in electricity-intensive industries. The effects are most pronounced for firms that sell primarily within the EU. Our results imply that investors focus on product price impacts, rather than just compliance costs. We find evidence that firms' net allowance positions also strongly influenced the share price response to the decline in allowance prices.

(*JEL* G14, Q50, H23, Q54, H22)

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1 Introduction

There is a long-standing perception of a fundamental conflict between the interests of business and environmental regulators. In many cases regulators apply policies that increase production costs, restrict production, or otherwise constrain the actions of firms. There is a rich literature chronicling the impacts that regulations such as the Clean Air Act have had on industrial activity.[1] With greenhouse gas regulation a controversial subject in the US and already under way in the European Union, the question of the impacts of these regulations on industry has taken center stage. As countries and regions around the world develop policies for limiting greenhouse gas (GHG) emissions, there is an understandably great interest in how these policies will impact the competitiveness, productivity, and profitability of the industries to which they are applied.

Measuring the economic impacts of GHG regulations obviously has direct relevance to setting the levels and timings of the regulations. Even setting aside the specific goals for GHG reductions, information about the overall magnitude and distribution of economic impacts has importance for the policy-making process. This is most starkly true in the case of cap-and-trade mechanisms, which create valuable new property rights in the form of emissions allowances or permits. These permits constitute the "currency" of cap and trade markets. They also provide an important tool to policy makers for distributing the revenues collected by the carbon regulation. The process of allocating emissions allowances, while inevitably containing a strong element of political maneuvering, is usually grounded in a desire to offset some of the cost impacts of the introduction of carbon regulation. Industries that claim to bear the brunt of the abatement costs usually stake the largest claim to allocations of allowances.

However, for most industrial enterprises, changes in direct abatement costs are only one piece of a complicated profitability puzzle. The introduction of a carbon dioxide (CO_2)

[1] For example, see Gray (1987), Greenstone (2002), Becker and Henderson (2002), Gray and Shadbegian (2003), and List *et al.* (2004).

price into an economy can have indirect impacts on firms that are not large CO_2 emitters. In most industries, increases in pollution prices will be reflected in output prices, and therefore revenues, as well as in costs. A more complete picture of these net impacts is necessary in any attempt to align allocations to the true economic impacts of CO_2 regulation on firms.

Indeed, the impact of regulations on profitability is ambiguous, even when those regulations have a substantial impact of costs. There are several mechanisms, ranging from restricting entry (e.g. Ryan, 2007) to raising rivals' costs (e.g. Puller, 2005) through which revenue increases can outstrip cost increases, enhancing profitability.[2] With cap-and-trade regulations, the free allocation of emissions allowances adds an additional source of revenue. In the case of GHG markets, these assets can total hundreds of billions of dollars.

Despite the politically motivated tendency to award emissions allowances proportionally to emissions, several papers have concluded that this likely amounts to overcompensation of the affected industries. These papers use various simulation methodologies to forecast potential impacts of carbon taxes or caps. Bovenberg and Goulder (2001) and Goulder *et al.* (2010) utilize general equilibrium models to assess the likely impacts of a carbon tax and various cap-and trade policies on a wide set of industries. Burtraw and Palmer (2008) simulate the US electricity sector under potential cap-and-trade scenarios. Smale *et al.* (2006) simulate several industries under a carbon cap in Europe using an assumption of Cournot competition. All these studies find that for many industries, compensation of less than 20 percent of emissions would offset the profitability impacts of regulation.

In this paper we study impacts on firms of the largest, in monetary terms, cap-and-trade market in the world - the EU's Emissions Trading System for CO_2. This is, to date, the most significant effort by far at regulating CO_2 emissions in the world. As a role model

[2]For example, Ryan (2007) demonstrates how the Clean Air Act significantly increased the sunk cost of entry in the Portland cement industry. Puller (2006) demonstrates how firms can profit from increased regulation by raising rival's costs, leading them to promote the adoption of those regulations.

for carbon cap-and-trade, the ETS has been closely scrutinized both within and outside the European Union. From the outset, the relative impact of the ETS on EU industries has been a controversial topic, one that has strongly influenced policies for the allocation of emissions allowances. During its first phase of operation from 2005 through 2007, the prices of emissions allowances in the EU market were quite volatile. While this volatility has sparked criticism about the design and implementation of this phase of the market, we take advantage of it in order to examine the impact of CO_2 prices on firms.

Rather than attempting to directly untangle the many competing effects of the ETS on firms, we focus on the stock market valuations of public-traded firms influenced by CO_2 regulation. Specifically, we examine the impact of a sharp devaluation in CO_2 prices in late April 2006 as an event study on the share prices of affected firms. Such an exercise can be interpreted in several ways. Under an assumption of fundamental market valuation these prices should reflect the market's expected discounted future profits of the firms. Even if one does not adhere to an assumption that the market fully reflects expectations of future profitability, the event provides a useful window into the beliefs of the market about the impacts of movements in CO_2 prices.

Our results imply that rather than being hurt by the imposition of CO_2 regulation, several industrial sectors benefited from the ETS. Indeed the sharpest declines in equity prices occur within industries that are the most carbon intensive. Such a response indicates that CO_2 prices play a significant role in determining product prices and revenues in many of these industries. We also examine the responses in relation to a measure of European market exposure, and find strong evidence that the benefits of higher CO_2 prices were concentrated amongst firms with the most exposure to markets within the EU.

In section 2, we briefly review the EU CO_2 market and its pricing from 2005-07 and examine the impact of the crash in permit prices in late April 2006. In section 3, we develop a simple model of the impacts of CO_2 costs on firm profitability in order to illustrate the potential impacts. Section 4 empirically examines the underlying elements of firm characteristics that influenced the response to the change in CO_2 prices. We conclude in section 5.

2 An Event Study of the EU ETS

The EU Emissions Trading System (ETS) was developed as one of the central mechanisms for which the European Union member states could achieve compliance with the commitments under the Kyoto treaty and is in many ways a remarkable accomplishment. The world's first significant cap-and-trade system for CO_2, the ETS covers over a dozen industries and 27 countries, including several that took on no Kyoto obligations. The ETS has been rolled out in phases. The first phase, running from 2005 through 2007, was intended as much to develop institutions and gain regulatory experience as to achieve substantial CO_2 reductions. The overall cap for the market was an aggregation of caps developed by each participating country through their "national allocation plans," previously analyzed by Betz *et al.* (2004). The EU established guidelines for the development of these plans, but member states were left with significant latitude. Efforts at setting an appropriate cap were complicated by the fact that, prior to 2005, the monitoring of CO_2 emissions of many facilities and countries was unreliable at best. Caps were supposed to be set in a manner that would place emissions reductions on a trajectory consistent with meeting the Kyoto targets. However, the effective stringency of the Kyoto targets varies greatly amongst EU member states, and the implementation plans themselves reflected large differences in these goals, as well as in the relative weight countries chose to give to the capped sectors covered by the ETS as opposed to those sectors counted under Kyoto but not under the ETS.

A second source of diversity amongst participating nations was their relative approach to assigning permits to the covered sectors. As chronicled in Ellerman and Buchner (2008), Kettner *et al.* (2008), and Joskow and Ellerman (2008), countries such as Spain, Italy, and the UK appear to have imposed more stringent caps and as a consequence the affected industries in these countries, particularly in the power sector, were allocated fewer permits than their observed emissions. These firms were therefore net buyers of permits within the EU. Industries in other countries, particularly in Eastern Europe, were observed to emit far less than their allocations.

Another important contrast lay in the allocation of permits across the various industrial sectors. Although there were differences in countries' approaches to the allocation of permits to their industries, some common themes emerge. In general, many regulated firms in the manufacturing sectors received more permits than they subsequently needed to cover their observed emissions. Those providing power and heat, predominantly electricity firms, were generally "short" of permits, but still received allocations equivalent to a substantial majority of their emissions.

Overall, by the end of phase I, available permits exceeded measured emissions by about 2.8%. Although the eventual surplus in permits led to a perception of intentionally lax regulation through "over-allocation," the picture is more nuanced. An ex-post realization of a surplus does not necessarily imply over-allocation, since a surplus of allowances can arise from either over-allocation or over-abatement. Since emissions prices were quite high for some of this period, it is natural to expect some abatement to have occurred, at least while emission prices were high. Studies by Ellerman and Buchner (2008) as well as Delarue *et al.* (2008) indicate that at least some abatement did take place. In addition, macro-economic and weather shocks may have played a role in lower than expected emissions, and specific directed regulations such as aggressive subsidies for renewable electricity production may have been sufficient to tip the market into surplus.[3] Importantly, none of this was known for much of the first phase, and it was only after the phase was more than 2/3 complete that the surplus conditions pushed emissions prices to near zero.

[3] See Convery *et al.* (2008).

2.1 ETS Market Performance

The most notorious aspect of the ETS during phase I was the volatility of the permit prices, which was greatly exacerbated by the fact that permits could not be "banked" for use beyond 2007. The ETS market was characterized by an early period in which prices were higher than anticipated and a later period in which the price eventually reached zero in the face of a surplus of permits that held no value beyond 2007. From the onset of trading in January 2005 through March 2006, prices rose steadily to over 30 Euro/tonne. While this price rise appears somewhat surprising in hindsight, given the eventual surplus of permits, it was not necessarily considered anomalous at the time. Many attribute the relatively high prices during this phase to the fact that prices for natural gas, which largely defines the marginal costs of reducing CO_2 emissions in the power sector through its substitution for coal, were steadily rising during this period.[4] In addition, while firms from countries "short" on permits were apparently relatively active in trading from the beginning, those from many "long" eastern European countries were not due to delays in integrating the regulatory platforms with that of the EU. This may have contributed to masking what later emerged to be a surplus of available permits.

The lack of reliable information about aggregate emissions was also a critical contributor to the volatility in prices. This was highlighted on April 25, 2006 when the first reports of country level emissions began to leak into the permit market. As can be seen in Figure 1, the reaction was dramatic. Over the next few days, the permit price as reported on the European Climate Exchange fell from €28 (per tonne) on April 25 to €14 on April 28. The price drop hit both phase I permit prices as well as permits covering phase II, which had begun trading in 2006. These initial reports were revised shortly after they were leaked to the public, and information from other countries was released in the following days. By May 15, when the final emissions totals were officially released, phase I prices had rebounded and then fallen slightly again to settle around €16.

[4] Joskow and Ellerman, 2008.

During this one month period, the general movements of prices for both the phase I and phase II permits had been generally consistent with each other, although the magnitudes were more muted in the case of the longer-term phase II permits. Later in 2006 the two prices series diverged for good, with the phase I prices starting a steady decline toward zero and the phase II series settling into a range around €20.

2.2 Equity Market Effects

We now turn to the question of how the sharp devaluation in permit prices in April 2006 impacted expectations about firm profitability. A few papers have empirically looked at different segments of the EU market. Sijm *et al.* (2006) examine the implications specifically for electricity prices in the Netherlands and Germany and find substantial pass-through of carbon cost. Convery *et al.* (2008) note that net incomes of several large electricity producers increased throughout phase I of the ETS. Two similar papers, Veith *et al.* (2009), and Oberndorfer (2009) examine stock market returns of electricity companies using a panel regression of share prices on CO_2 prices throughout the phase I period. Both find that share prices of large electricity producers who were regulated under the ETS were positively linked with prices for CO_2. However in contrast to our results, Veith *et al.* find that share prices of "clean" electricity producers not covered under the ETS had no significant response to CO_2 prices.

While these latter two papers also study equity market impacts of ETS prices, our work differs in several important ways. First, we choose to focus on the specific 3 day event of the price crash in an attempt to isolate the most dramatic ETS price change from other movements in the ETS price that could be either potentially endogenous or correlated to other market drivers such as macro-economic or commodity price shocks. Second, we examine a broad set of industries that were both directly and indirectly impacted by ETS regulations. Third we explicitly examine measures of the net trading position for a subsample of firms.

In this paper we also utilize equity prices of publicly traded firms. It is important to note that many firms directly subject to the CO_2 cap, as well as those in impacted industries, are privately held or government owned. A large number of publicly traded firms were also affected, however, and we focus our attention on these firms. We employ a standard event-study approach.[5] We examine firms contained in the Dow Jones STOXX 600 index, which is similar to the S&P 500 but covers European firms.[6] We focus on the three days after the initial leak of permit market information, the daily returns for April 26-28. Several papers have utilized an event study approach to assess the impact of environmental regulation on firm profits, including Kahn and Knittel (2002), Linn (2006) and Linn (2010). Because this approach has usually utilized a political or legal decision as the "event," a common concern has been that information may have leaked into the market before the examined event date. Here we can be confident that there was little leakage of information as this information would have impacted the CO_2 price, which was steadily rising up until our event date.

We utilize the following specification for investigating the potential for abnormal returns during this event window. For firm i, industry j, and day t:

$$S_{ijt} = \alpha_i + \beta_i M_t + \gamma_j EVENT_t + \epsilon_{ijt}, \tag{1}$$

where S_{ijt} is the firm's daily return (i.e., the percent change in the stock price), M_t is the daily return of the market index, and $EVENT_t$ is a dummy variable that is scaled according to the length of the event window. For our base specification, where the event window is 3 days, $EVENT_t$ will be scaled by 1/3 so that γ_j represents the industry-average, cumulative excess return for industry j during the event window. We estimate γ_j for each two-digit NACE industry classification.[7] For each table, we report the most

[5] Fama *et al.*, 1969; more recent surveys include Brown and Warner, 1985, and MacKinlay, 1997

[6] We chose this index because of its breadth of firms and of geography. Other commonly cited European Indices such as the FTSE 100 and the DAX are more limited in coverage of European countries and industries.

[7] NACE is the European standard classification of productive economic activities. The US classification, NAICS is more widely used in the literature, but is more difficult to link to the characteristics of European

conservative set of standard errors among the three sets estimated: robust ones, and those clustered by either firm or two-digit industry codes.

Table 1 summarizes the cumulative abnormal returns by industry, γ_j, as well as their cumulative returns (from regressions imposing $\beta_i = 0$). Many of the largest significant declines were in industries that feature prominently in the EU ETS: Basic Metals, Oil & Gas Extraction, and Utilities. However, there are also notable declines in such industries as Sewage and Refuse, Land Transportation, and Water Utilities. As we describe below, each of these industries are relatively large users of electricity and sell to relatively local markets. Conversely other industries such as chemicals and food manufacturing, which also large electricity users but have sales that are not highly concentrated in the EU, experienced little change during the event.

These results summarize general effects but do not account for firm heterogeneity within each classification. In the following sections we provide some structure to the analysis by describing the theory of how input cost shocks, such as the ETS price drop, influence firm profits.

3 Emissions Regulations and Firm Profits

Having established that the carbon price-crash event impacted sectors differentially, and that "dirtier" sectors appear to have performed the worst during the event, we turn to a deeper examination of the economic mechanisms that produced this result. We briefly discuss a theoretical model considering the potential impacts of environmental regulation, or more specifically emissions costs, on firm profitability and performance. The model provides a useful framework for decomposing and illustrating the various potential impacts, both positive and negative, of emissions costs on firms. In the following sections, we then present empirical tests of which market elements and firm characteristics most influenced

firms and countries. A previous version of this paper utilized NAICS and found similar results. Weiner (2005) evaluates several industrial classification schemes and finds drawbacks in each.

market performance during this period.

Consider firm i producing for a market represented by the demand curve, $P(q_i + q_{\neq i})$, where $q_{\neq i}$ represents total production by other firms in this market. The firm is subject to cap-and-trade regulation of its emissions, which are in turn a function of its emissions rate, r_i, and its total production, q_i.[8] We assume that the production technology determines the emissions rate, $r_i(q_i)$ and that this rate cannot be changed over the time horizon we are considering. The per-unit price of emissions allowances is τ, resulting in direct compliance costs of $\tau r_i(q_i)q_i$. However, the firm may possess allowances A_i equal to its initial allocation less net sales. Considering both input and environmental costs, the profits of firm i can be represented as

$$\pi_i = P(q_i + q_{\neq i})q_i - C_i(q_i, \omega) + \tau A_i - \tau r_i(q_i)q_i \tag{2}$$

where the function $C_i(q_i, \omega)$ represents the total cost of producing q_i with a vector of input costs, w.

In Appendix A, we derive the following expression for how changes in permit prices affect the profits of firm i:

$$\frac{d\pi_i^*}{d\tau} = P' \frac{\partial q_{\neq i}^*}{\partial \tau} q_i^* + \left[P' \frac{\partial q_{\neq i}^*}{\partial \omega} q_i^* - \frac{\partial C}{\partial \omega} \right] \frac{\partial \omega}{\partial \tau} + [A_i - r_i q_i^*] \,, \tag{3}$$

where q_i^* and π_i^* are consistent with profit maximization.

The individual terms in equation (3) illustrate the competing potential effects of a change in the allowance price. First, revenues may increase due to the fact that other firms in the industry have collectively responded by reducing output in direct response to

[8] The model is intended to be general, encompassing both perfectly competitive industries and those in which individual firms have market power. However, it is important to also acknowledge aspects of oligopoly competition that are not explicitly represented within this framework. In oligopoly settings, cost shocks such as environmental regulations can increase profitability by increasing the severity of market power in an industry. In a dynamic setting, the environmental regulation could serve as a barrier to entry or even as a collusive focal point. Even in a static setting, the imposition of an environmental tax can increase margins under certain demand structures (Seade, 1985).

the permit price. This is similar to a "raising rivals' costs" effect.[9] Under the assumption that firms would reduce output in the face of an increase in allowance costs, this term would be positive. Second, the middle term on the right hand side of (3) captures the impact of changes in profits from the indirect effect of permits through input costs. Environmental regulations may increase the price of inputs like electricity that, in turn, effect the costs of downstream firms and therefore prices in the product market. This effect is theoretically ambiguous. We can think of these first two components as the (net) "revenue effect," or in other words, the pass-through of the cost of allowances on to product prices.

Third, the last term reflects the effect on direct compliance costs of changes in allowance prices. If a firm is a large emitter and has a low allocation of allowances, it will have high cost exposure to allowance prices. Conversely, if a firm is holding more allowances than it expects to consume in its own production, its value will be enhanced by higher allowance prices: i.e., the firm is "short" in allowances, $A < rq$.

For each firm, the magnitude of these effects will depend upon several factors: (1) whether the firm produces in a market that is subject to the environmental regulation (either directly or indirectly through input prices); (2) the price elasticity of demand in that product market; (3) how many permits the firm owns, and (4) the convexity of costs with respect to allowance prices in an industry. Figure 2 helps to illustrate these factors for a given competitive, product market. We assume that the firms in this market face demand curve D, and have a supply function reflecting marginal costs $c_{\tau 1}$ before the imposition, or increase, in allowance prices. D is assumed to be unaffected by a change in allowance prices.

The classic analysis of the incidence of taxation implies a vertical shift of the marginal cost curve to $c_{\tau 2}$. In the context of environmental regulation, this is equivalent to assuming that emissions rates are constant for all quantities produced. In this case, the producer surplus is reduced from the sum of areas B and C to the area A in Figure 2a. The allocation of permits or emissions tax revenues would then be critical in determining the net effect of

[9] Salop and Scheffman, 1983

the regulation. If firms in this market received a free allocation equivalent to 100% of their *ex post* emissions, this would be a transfer equivalent to the areas C and D, which totally offset the increased regulatory cost. As long as the demand for the product is sufficiently inelastic (*i.e.*, as long as the new equilibrium market quantity is at least the monopoly solution without the regulation), profits will improve because revenue (less production costs) will increase without any increase in environmental costs. Indeed as Bovenberg and Goulder (2001) demonstrate, only a relatively small allocation of emissions allowances is necessary to fully compensate many industries for changes in profits due to CO_2 costs.

Even without an allocation of allowances, the impact on firm profits can be ambiguous. This is due to the fact that there are both heterogeneous firms and production technologies within most markets. Consider a case where emissions rates are increasing with production quantities, as illustrated in Figure 2b. The increase in allowance costs now rotates marginal costs, and therefore prices in this perfectly competitive circumstance. The increase in *average* costs is well below the increase in marginal costs, however. Now the new producer surplus, area A, could be larger than the previous surplus of B and C. A similar effect could arise if an individual firm has technology with a lower emissions rate than its rivals. Again product prices could rise faster than the firm's average production costs.

The magnitude of the revenue effect depends upon consumers' burden for the allowance price: If most of the incidence of an increase in emissions costs is passed on to consumers, firms can profit from more stringent regulation. In contrast, if a firm sells in a market with a high demand elasticity, then even a substantial convexity in the marginal cost curve would not compensate for the fact that the producer is absorbing the bulk of the incidence (Figure 2c).

This discussion is meant to illustrate the varied potential effects and emphasize the importance of several key industry characteristics in determining the net effects of environmental regulations. In the following sections, we develop several proxy variables meant to reflect these characteristics in order to examine the market return of individual firms and industries in response to a substantial decline in emissions costs.

3.1 Product Prices and Revenues

Two of the most direct channels in which the ETS price can impact firm profits is through the direct cost effect of the regulation as well as the impact on the prices of the products sold by the regulated firms. To the extent that industry prices rise faster than the costs of a specific firm, that firm can benefit from the regulation.

One notable market impact of the ETS price crash is the interaction with wholesale electricity prices. Figure 3 illustrates the clearing prices of several electricity futures contracts traded on the European Energy Exchange. The figure plots the daily clearing prices of contracts for "baseload", or all-hour, electricity delivered to the German and to the French grids during the last two quarters of 2006 and the first two quarters of 2007.[10] While there is seasonality in the overall levels of these clearing prices, all clearly and immediately respond the EU ETS price change. These continental electricity prices for both near term and longer term deliveries all fell by about 10% between April 25 and May 3, 2006. As we discuss below, our results indicate that equity market reaction in general seemed to be focused on the impacts of ETS prices on revenues rather than costs in this and other sectors.

This impact would not be felt uniformly by firms within the industry. This fact is highlighted by Table 2, which summarizes the effects for firms contained in the Electricity sector, using auxiliary data on electricity generation units from the Carbon Monitoring for Action project (carma.org) published by the Center for Global Development, Washington DC.

The second column of Table 2 presents the event coefficient for each firm, while columns 3-5 summarize some key characteristics of the firms. When one bores down into the detailed characteristics of firms in the electricity sector, some suggestive patterns begin to emerge.

[10]The source of these data is the European Energy Exchange. www.eex.com.

The biggest declines were concentrated within firms who produce electricity with relatively low CO_2 emissions, such as the hydro or nuclear intensive firms Fortum, British Energy, and Electricite de France. Some coal intensive firms such as Drax and RWE registered declines, but they were more modest than those of the "clean" producers. Last network operators such as National Grid and Red Electrica, with no position in the production or sale of electricity, registered almost no impact.

These results are consistent with an explanation of the effects that emphasizes the importance of revenue impacts in the product markets. All the firms in Table 2 who sell bulk electricity experienced declines in revenues, and only some experienced significant declines in production costs. Many of these firms were also substantial holders of emissions permits at the time of the crash in permit prices. In the following section we develop several more general indices meant to capture the relative sector level and firm specific characteristics that could influence the permit price effects and test their relevance on market returns during this event period.

4 Testing Determinants of Profitability

In the following sub-sections, we examine which industry and firm characteristics determine the profitability of some firms in the face of CO_2 price changes. Recall that profitability drivers include cost exposure to the emissions market through one's emissions relative to one's allowance holdings, as well as potential revenue effects driven by cost impacts on competitors within an industry.

4.1 Asset Value of Permit Holdings

We first examine the effect of permit allocation, and emissions on the performance of share prices during the event. For this task we utilize the emissions data contained in the EU's Community Independent Transaction Log (CITL). This dataset contains facility level information on the allocation and emissions of over 12,000 facilities throughout the EU. Unfortunately, firm ownership of facilities is reported inconsistently within the CITL, making necessary a manual matching of facilities to firms, and then to individual stock listings.

We were able to match 124 publicly-traded firms in the largest sectors regulated by the ETS.[11] For each of these firms, we take total 2005 emissions and permit allocations aggregated over all covered facilities owned by the firms.

We examine whether these firms' permit allocations and emissions by themselves explain abnormal returns. Given a drop in permit prices, those firms with positive net permit positions will lose more profits than others with a negative net position, all else equal. In theory this will be reflected in the stock price. We test this by estimating the following equation:

$$S_{ijt} = \alpha_i + \beta_i M_t + \gamma_j EVENT_t + \mu(\frac{A_i - E_i}{C_i})EVENT_t + \eta_{ijt}, \quad (4)$$

where A_i is the historic 2005 allocation, E_i is the historic 2005 emissions (as measured in the spring of 2006), and C_i is the firm's historic market cap in Euros (on April 25, 2006). In order to control for industry average differences, we include industry fixed effects.

Note that, although the CITL registers all transactions, only the allocations and emissions data are currently publicly available. Therefore we do not know the actual holdings of a given firm on any day, only their initial allocations. Our values for $(A_i - E_i)$ should be considered only as a proxy for firms' actual net positions at the time of the event. Importantly, the broader market also did not know these positions and was relying upon the same data, which were finalized on May 15, that we utilize here.

The net permit position $(A_i - E_i)$ is normalized by market capitalization. This is done because larger firms could have greater variation of net permits. Furthermore, this

[11] Matching occurred in two stages. In one stage, primary internet domain names for firms (SP500 and STOXX600) were gathered from the ORBIS database and these were matched to the internet domain names taken from the CITL records of email addresses. In the second stage, facilities were matched by hand through internet searches on the largest emitting facilities and firms drawn from the largest emitting sectors.

normalization implies a μ coefficient of the change in market capitalization given a change in net permits.

If profit impacts were driven completely by net emissions costs, we hypothesize that the coefficient μ would equal roughly the drop in permit price times three, or -42. A firm with, say, one million tonnes of excess permits in 2005 may be expected to have extra permits in 2006 and 2007. The value of these unused permits fell by the drop in the permit price, which was around €14. Hence, this hypothetical firm would have lost €42 million: 1 million tonnes/year * 3 years * -€14/tonne.

Table 3 reports estimates in three panels. Panel A includes the full sample with estimates controlling for industry fixed effects. As described above, many industry classifications were "long" in permits during this period. The important exception is the power industry which was net short of permits (Ellerman and Buchner, 2008). We therefore estimate the power industry, as the one segment known to be short, separately in Panel B. In Panel C, we estimate the influence firm-level emissions and allocations on all other industries, controlling for industry fixed effects.

In column 1 of each panel, we report the coefficient on net position. For all firms, the coefficient, -1.11 (s.e. of 15.16), is statistically insignificant and can easily be rejected as being consistent with theory, i.e., equaling -42. Even after splitting the sample as in Panels B and C, we find insignificant coefficients.

Given the lack of market information about permit trading, investors were unlikely to know the exact net position of firms, and may have had difficulty even estimating the sign of net position. Figure 4, which plots the 124 firms' permit allocation and emissions during 2005, demonstrates this point. Many firms had been allocated permits that were very highly correlated with their 2005 emissions levels. We find that the log of initial allocation explains over 95 percent of the variation in the log of 2005 emissions.

In Table 3, we next examine whether the abnormal returns were correlated with a firm's level of allocation or emissions, again normalized by market cap. We find no evidence of this in Panel A. However, the picture becomes more clear once we split the sample as in Panels B and C. A clear distinction between the power sector and other industries emerges. Within the power sector, firms with high levels of emissions outperformed the “cleaner” firms when the allowances prices fell. There is a strong relationship between emissions and changes in market capitalization, with each ton of emissions improving market cap by €7.65. Firms with higher allocations also had better returns, but recall that emissions and allocations are highly co-linear, so this is likely also an emissions effect.

In Panel C, we see that firms in the other industrial sectors, which were net long on permits, experienced the opposite effect. Firms with higher allocations suffered the largest declines when the permit price fell, with each added tonne of allocation implying a reduction of €26.71 in market capitalization. As with the power sector, both emissions and allowances produce nearly identical coefficients, reflecting the strong correlation of these two variables.

This firm-level analysis of permit holdings and emissions implies that, within industries that were net long on permits, dirtier firms suffered the largest declines. This is consistent with a market expectation that these firms had suffered the largest decrease in aggregate permit asset value, as these firms were the largest holders of permits within their industries, and their asset values in permits exceeded their emissions liabilities. For the power sector, it is the cleanest firms that suffer the most. This is consistent with a market focus on the impact of permit values on electricity prices, combined with a view that dirtier firms experienced a net decline in their abatement costs to somewhat offset the decline in product prices. These dirty firms in the power sector still experienced abnormal negative returns, but they were more modest declines than those of the cleaner firms.

All told, this is evidence that emissions and asset holdings had some influence on market response to the carbon price crash. As we have argued, carbon prices would also be expected to impact revenues of various firms. It is worth noting that the results on emissions and allowances presented in Table 3 are robust to the inclusion of the various proxies for revenue effects that we discuss in the following section.

4.2 Tests of Revenue Effects

Recall from Section 3 that the revenue effect depends on how a cost shock in an industry affects the output prices. In order to test the importance of these factors, we again estimate the effects of the event, but now decompose the cumulative abnormal returns during the event window by estimating the following equation:

$$\begin{aligned} S_{ijt} &= \alpha_i + \beta_i M_t + \delta_1 EVENT_t + \delta_2 Dirty_j EVENT_t + \delta_3 EE_i EVENT_t \\ &+ \delta_4 Dirty_j EE_i EVENT_t + \delta_5 NoEE_i EVENT_t + \delta_6 Dirty_j NoEE_i EVENT_t + \nu_{ij}, \end{aligned} \quad (5)$$

where β_i as before measures a stock's relationship to the broader index, $Dirty_j$ is a measure the "dirtiness" of an industry, and EE_i is a firm's revenue exposure to the EU market. Because, as we explain below, we have EU revenues for only a subset of our sample, the dummy variable $NoEE_i$ is included to indicate whether EE_i is missing.

We examine two different measures for $Dirty_j$: Dirty output (DO_j) measures the carbon intensity, while dirty input (DI_j) measures the electricity and natural gas intensity. In order for δ_1 to capture the average effect, we demean DO_j, DI_j, and EE_i. We describe each of these variables in more detail below.

Dirty output is the average carbon intensity of a sector, measured at the two-digit NACE level. The data sources include the CITL emissions data and Thomson's Datastream financial data. For all sectors j where at least one firm was matched in the CITL, DO_j is given by the following formula:

$$DO_j = \frac{\sum_{i \in (j \cap CITL)} Emit_i}{\sum_{i \in (j \cap CITL)} S_i} \quad (6)$$

where $Emit_i$ is the facility-level emissions in 2005 from the CITL and S_i is the 2005 revenue of firm i in thousands of US dollars. We sum over the 124 firms that we identified in the CITL. The subscript j indexes two-digit NACE sectors, and $CITL$ indexes firms contained in the CITL emissions data set. Emissions intensity for *any* firm in a given two-digit NACE sector will therefore be based upon the measured emissions of firms matched with CITL data in that sector. There were 345 firms contained in the STOXX 600 index drawn from these sectors.

Dirty input is the average energy intensity of a sector, also measured at the two-digit NACE level. We use input-output tables of industrial activity where we aggregate sectoral expenditures and output in 2004 for the EU 27 countries.[12] The value DI_j is the ratio of expenditures (in 2004 Euros) on the utility energy sector (NACE code 40: Electricity, gas, steam and hot water) over total output (in 2004 Euros).

Recall from Section 3, the revenue effect depends not only on how dirty an industry is, but whether a firm sells into markets where the bulk of producers are likely to be subject to the regulation. We use the concentration of a firm's revenues in the EU as a proxy for the exposure of a firms' product markets to the regulation. The variable EU Exposure (EE_i) is the percentage of total sales earned in Europe and measures the company's revenue exposure to prices in the EU market.[13]Note that our theoretical model also pointed out the importance of demand elasticity. To the extent that it captures the exposure of a firms competitors to the regulation, EE_i can be thought of as a measure of the sensitivity to carbon prices of a firm's *residual* demand, or the term $P' \frac{\partial q^*_{\neq i}}{\partial \tau}$ in equation 3.[14]

In the sample of 600 firms, roughly 60% are in sectors covered by the ETS and therefore have non-zero values for DO_j. Given that unregulated firms experience effectively no direct carbon-cost exposure we treated these as equivalent to zero emissions firms. In the case of EE, the data were not available for the full sample of firms. Instead, we have measures of EU exposure for 260 firms from 39 two-digit NACE codes. Since we have no information on the EU exposure of the firms with missing data, we include a dummy variable for $NoEE_i$.

[12] Data are reported by the European Commission through the Eurostat system: http://epp.eurostat.ec.europa.eu

[13] These data come from come from Eurostockcity, who was the data provider to Yahoo Finance UK.

[14] In a previous draft of this paper, we used measures of trade exposure to proxy for elasticity but found insignificant results with these proxies. Unlike the trade data, the EU exposure variable provides us with firm-level variation as well as broader coverage of non-goods sectors.

Table 4 provides the summary statistics for 45 two-digit NACE sectors. For each sector, the table reports average abnormal returns during the event window. In addition, we report the sectoral characteristics DO_j and DI_j, and the sectoral means for EE_i , $NoEE_i$, and market capitalization. The mining, metals, and paper sectors are the most utility energy intensive after the power sector: with mining experiencing some of the largest abnormal declines during the event window. Utilities have the highest carbon emissions intensity: its average stocks had an abnormal decline of about 1.7 percent.

4.2.1 Results

Table 5 reports the results of different variations of (6). The overall event produced a one-half of one percent decline for the full sample. The second and third columns report the results controlling only for dirty output or dirty input, respectively. The fourth column controls only for EU exposure. The fifth and sixth columns interact DO and DI with EU exposure, under the intuition that a revenue effect would be strongest in relatively "dirty" industries that are also heavily concentrated in the European market.

From Table 5, it is clear there is a relationship between carbon intensity and performance during the event window. Firms from industries with high emissions (large DO) or relatively dirty inputs (*e.g.*, high electricity and gas usage) saw their share prices decline. This is suggestive of a larger revenue effect in dirtier industries. Firms in high DO sectors will have experienced a decline in their competitor's, as well as their own, marginal costs. For the dirtiest industries, the coefficients on DO and DI imply similar effects.[15] This may reflect the high correlation between the two measures.[16]

It might at first seem counter-intuitive that the firms most directly impacted by CO_2 regulations would be the greatest losers from a decline in CO_2 prices. Recall that these

[15] The maximum demeaned DO measure is .89 while the maximum demeaned DI measure is .18. Thus, column (2) implies an event effect of -.0152 for the dirtiest DO industry, while column (3) implies an event effect of -.0148.

[16] In fact, when both DO and DI enter simultaneously, the coefficient on DO remains roughly the same (-.018) and but is very imprecisely estimated (a s.e. of .031). DI is also insignificant: .003 (.146).

values are measuring the relative carbon intensities of *industries*, not the individual firms within industries. Thus we interpret these results as being consistent with the hypothesis that product prices, and therefore revenues, were negatively impacted by the CO_2 price shock. Although costs were also reduced, either through the direct or indirect exposure to CO_2 regulation, it appears that the revenue effects were stronger. For regulated industries, this is almost certainly a consequence of the fact that allocations were closely linked to emissions, as illustrated above. For these firms, the revenue effects would naturally be the strongest as the reductions in costs are largely offset by a concurrent reduction in the value of permit holdings.

This conclusion is reinforced when we examine the interaction of DO and DI with a firm's exposure to the EU market. First note that, by itself, EU exposure is an insignificant determinant of the event and the indictor of whether a firm is missing EE data is also insignificant (see column (4)). In column (5), DO is interacted with EU exposure. The interaction term between DO and EE is highly significant and negative while the DO coefficient is no longer significant. The interaction between $NoEE$ and DO is insignificant. As we have demeaned the variables, this suggests that the firms not reporting EE are similar to the average firm that does report. Overall, these findings imply that it was firms with high EU exposure who were largely driving the negative value on DO seen in column (2). Firms that were both highly concentrated in Europe and selling products produced by dirty industries experienced the sharpest declines. In the last column, the coefficients on the interaction between DI and EE are large in magnitude but imprecisely estimated.

4.2.2 Robustness

In Table 6, we examine the robustness of these results in several ways. The first column repeats our main results: Column (5) of Table 5. Column (2) examines the question of the appropriate time window for the event. From Figure 1, we see that the volatility in permit prices continued beyond the three-day window examined above. Here we examine a 30-day event window we call $BIGEVENT$, consisting of five days prior and 25 days after April 25, 2006 and perform the same analysis as (6). We find qualitatively similar results as in Table 5 though much less precisely estimated. For example, there was a three percent reduction in the average stock performance. Interestingly, the impacts of EU exposure are much stronger than during the shorter event window. While firms in "clean" industries with EU exposure do better during the event, the coefficient on the interaction of "dirty" and EU exposure is still negative but no longer significant. The overall market experienced much larger declines during the large window, while those concentrated in Europe performed disproportionately better.

Column (3) adds a measure of a firm's debt-to-equity ratio interacted with the event window. Note that the net present value of all future profits equals the sum of equity and debt. By including the debt-equity ratio, we test the robustness of our results that the findings are representative of changes in profits, not just equity. Although debt-to-equity is a significant in some specifications, it does not change the underlying picture with regards to dirty inputs and outputs during the short event window.

Column (4) tests the importance of the CAPM framework to the results by testing the event on the unadjusted cumulative returns (e.g. no β term) of the shares. This is meant to address the concern that the correlated event moved the market index and that we are understating the effect of stocks. The results are similar to our main ones.

Column (5) examines the sensitivity of the results to the power and heat sector. Recall that this sector was one of the "dirtiest" in terms of both outputs and inputs. When the power and heat sector (NACE 4011) is excluded, the results are qualitatively similar: the interaction between EE and DO is of similar sign and magnitude but noisier. In particular, the coefficient is significant with robust standard errors but not when they are clustered by two-digit NACE codes (as reported in the table). Finally, additional robustness tests not reported here examine possible spillovers to the US, and run falsification tests for a previous spring.[17]

[17] In Bushnell, Chong, and Mansur (2009), we replicate the analysis using US data for the stocks in the

5 Conclusions

The development and application of any significant new environmental regulation will involve some level of debate over its economic impacts. This is particularly true in the case of regulations to combat climate change because the stakes are so high. The annual value of permits consumed in the European ETS market we study reached nearly $60 Billion. A market in the United States would be 2 to 3 times the size of the European market. These values are an order of magnitude larger than any other previous emissions trading markets. These sums have generated intense interest in the potential incidence of these costs, and many industries are making the case for some form of free permit allocation to offset these costs.

However, the cost impact is only one part of the story from the perspective of firms and industries. The impact of emissions costs on revenues is another critical consideration. The policy implications of this full portfolio of impacts has drawn us to examine the European ETS market. We have used an event-study approach to analyze the response of the stock market to the devaluation of CO_2 permit prices in late April 2006. This provides one of the first opportunities to empirically test the impacts of CO_2 regulation on major industries and firms. By looking at the impact of a sharp decline in CO_2 prices on the equity prices of impacted firms, we can get a strong sense of what the market believes to be the net impacts of CO_2 regulations.

The story that emerges from an examination of this event is that the equity markets were strongly focused on revenue effects. Our results demonstrate, fairly robustly, that the share prices of firms from the "dirtiest" industries experienced the largest abnormal

US Standard and Poors 500 index. When all factors are considered, the only variable with a significant impact on returns is the *DO* index variable, which is positive, indicating that dirty firms experienced an increase during this period. One possible interpretation is that the event in the EU lowered expectations about the probability or the cost of future regulation in the US. We have also replicated the analyze a similar time frame from the year 2004, a date *before* the EU CO_2 market came into existence, as a form of falsification test. Although certain characteristics were significant in determining the abnormal returns of shares during this 2004 period, the results are quite different from the results from the 2006 CO_2 price crash.

declines during this period. For firms that are directly regulated under the ETS program, consideration of permit holdings almost certainly influenced investor response. Although our data on allocations appear insufficient to explicitly identify a "net holdings" effect, we do find evidence that allocations played a role in the market's response to the CO_2 price crash.

Within the power sector, which was as a whole "short" of permits, the share prices of firms with the highest emissions rates, perform better than the "cleaner" firms within this sector. The share prices of many of these high emissions firms did experience abnormal declines, but these declines were less severe than those of their low carbon intensity competitors. The fact that very low-carbon emissions firms declined the most gives strong indication of the market's focus on how declining CO_2 prices would reduce the revenues of these firms through lower electricity prices. The fact that the high emissions firms still experienced declines highlights the fact that the market also understood that these firms were holding large portfolios of allowances and experienced a loss in that portfolio that largely offset their cost savings from lower CO_2 prices. Within other industries that were in aggregate allocated more allowances than were consumed, those firms with the largest allowances experienced the largest abnormal declines.

It is important to recognize the many caveats that must be applied to interpreting these results. The ETS was a very new market, which was one of the causes of the volatility we utilize here. It would be heroic to assume that the stock market completely and accurately processed the information that emerged in late April 2006. In addition, while the crash affected both near-term and long-term CO_2 prices, the impact on the near-term Phase I prices was much more pronounced. The events of 2006 may also have impacted expectations about future allocations of emissions permits, as well as expectations about prices. Because our event study uses the same time window for all stocks, any contemporaneous events could also be causing the abnormal returns. We looked for sector-specific announcements in this period. Specifically, oil prices did not change dramatically.

Nonetheless, these results are largely consistent with what simulation studies had predicted could be the case for many of these industries. These studies forecast an increase in revenues that would largely offset the increase in regulatory costs. In fact, our results imply that for clean firms in dirty industries, these revenue effects are larger than cost increases. These are important facts to bear in mind when setting policies regarding allocations to impacted industries. In many cases, those directly or even indirectly impacted by CO_2 costs may need little compensation. Instead it is their customers who will be most affected.

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Appendix A: A Model of Impacts of Allowance Prices on Profits

Recall equation (2) in the text: firm i profits are

$$\pi_i = P(q_i + q_{\neq i})q_i - C_i(q_i, \omega) + \tau A_i - \tau r_i(q_i)q_i. \tag{2}$$

The impact on profits of a marginal change in τ can be expressed as:

$$\frac{d\pi_i}{d\tau} = P\frac{dq_i}{d\tau} + P' \cdot \left[\frac{dq_i}{d\tau} + \frac{dq_{\neq i}}{d\tau}\right] q_i - \frac{\partial C_i}{\partial q_i}\frac{\partial q_i}{\partial \tau} - \frac{\partial C_i}{\partial \omega}\frac{\partial \omega}{\partial \tau} + A_i - r_i q_i - \tau\left(r_i' q_i + r_i\right)\frac{dq_i}{d\tau}. \tag{A.1}$$

Assuming that firms maximize profits with respect to q, we can write the optimal output q_i^* as a function, $f(\cdot)$, of the competitors' production, the direct effect of the permit price, and the indirect effect through input prices: $q_i^* = f(q_{\neq i}, \tau, \omega(\tau))$. Next, define $\pi_i^* \equiv \pi_i(q_i^*)$. For shocks that have marginal influence on q_i, the envelope theorem implies:

$$\frac{\partial \pi_i^*}{\partial q_i} = P + P' q_i^* - \frac{\partial C_i}{\partial q_i} - \tau\left(r_i' q_i^* + r_i\right) = 0. \tag{A.2}$$

In other words, the change in profitability though own output would be negligible. However, there are still effects relating to changes in market prices due to the responses of other firms in the industry, direct costs, and the value of net allowance holdings. This can be seen by combining equations (A.1) and (A.2):

$$\frac{d\pi_i^*}{d\tau} = P'\frac{dq_{\neq i}}{d\tau}q_i^* - \frac{\partial C_i}{\partial \omega}\frac{d\omega}{d\tau} + A_i - r_i q_i^*. \tag{A.3}$$

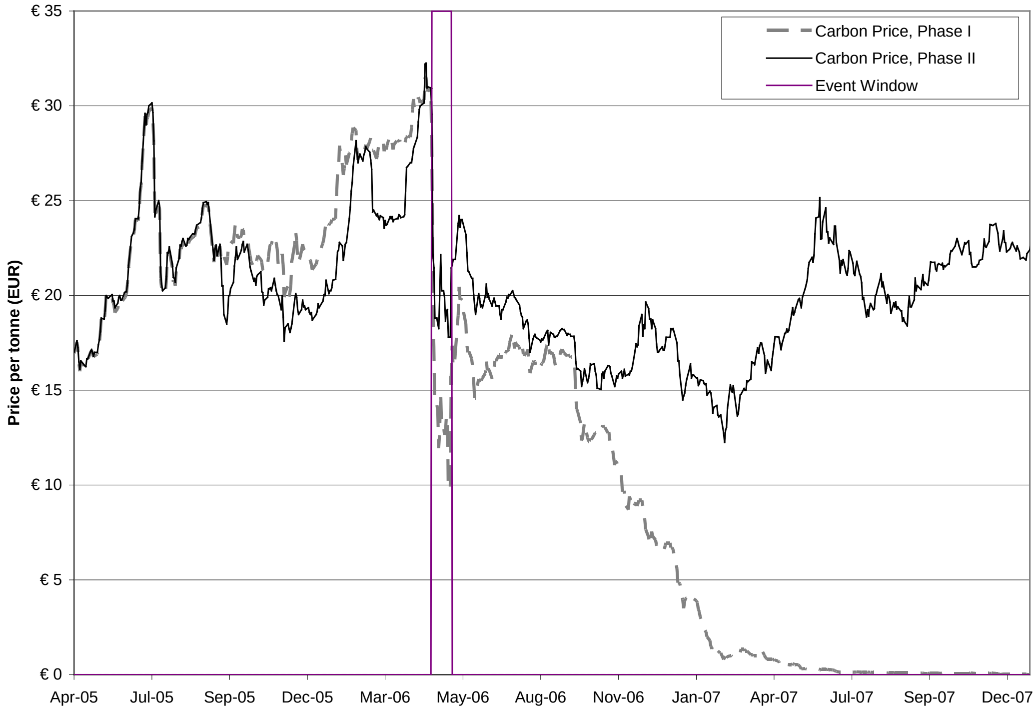
Finally, by recognizing that each firm's optimal output response can be written as a $f(\cdot)$ function, we define the effect of a change in τ on other firms' output as the sum of a direct component and an indirect effect through input prices:

$$\frac{dq_{\neq i}^*}{d\tau} = \frac{\partial q_{\neq i}^*}{\partial \tau} + \frac{\partial q_{\neq i}^*}{\partial \omega}\frac{\partial \omega}{\partial \tau} \tag{A.4}$$

From this, we derive equation (3) that we restate here:

$$\frac{d\pi_i^*}{d\tau} = P'\frac{\partial q_{\neq i}^*}{\partial \tau}q_i^* + \left[P'\frac{\partial q_{\neq i}^*}{\partial \omega}q_i^* - \frac{\partial C}{\partial \omega}\right]\frac{\partial \omega}{\partial \tau} + \left[A_i - r_i q_i^*\right] \tag{3}$$

Figures and Tables



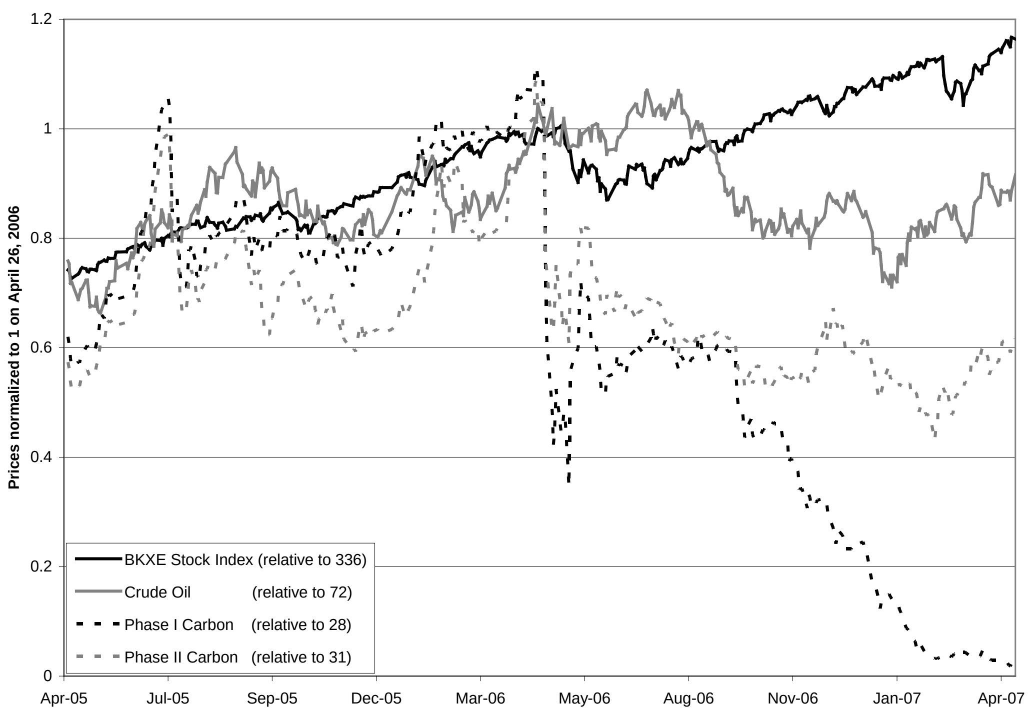


Figure 1: EU Carbon Prices, Stock Index, and Oil Prices

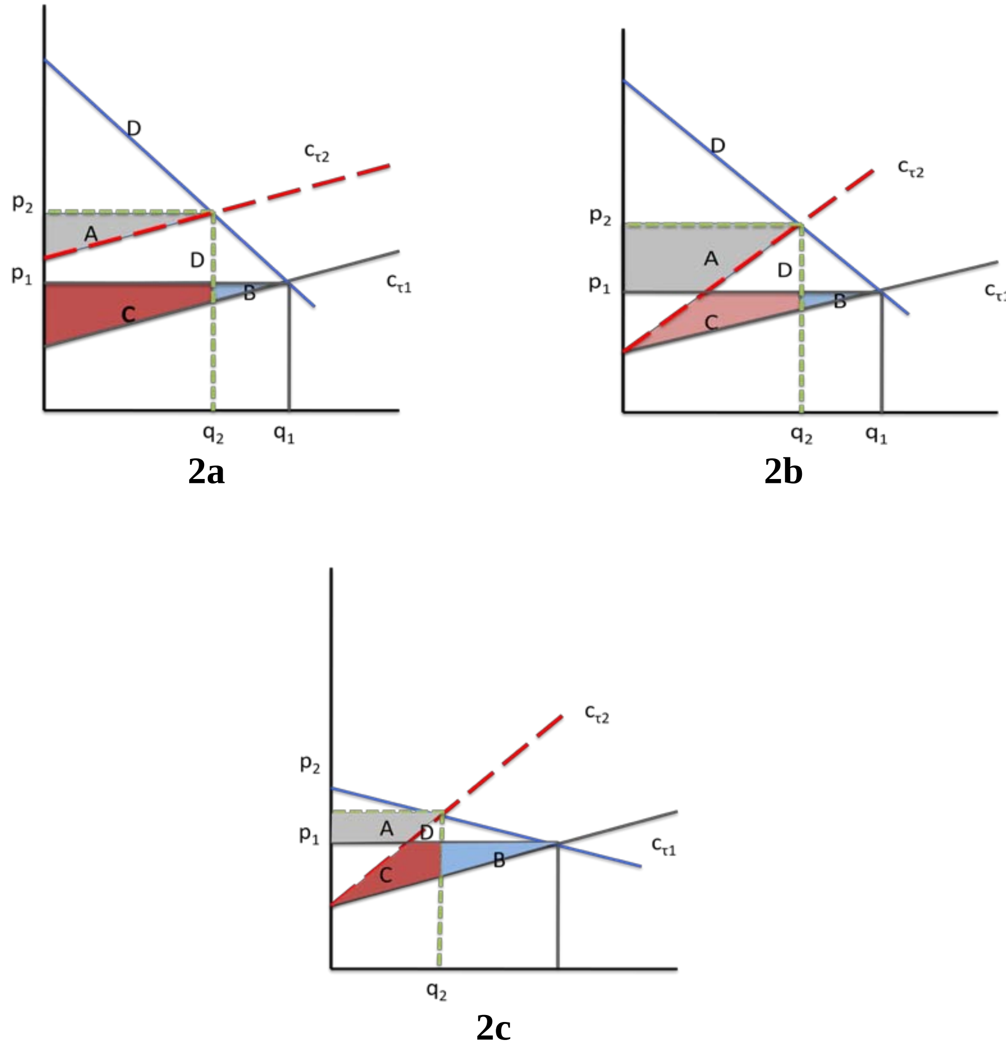


Figure 2: Theoretical Change in Producer Surplus under Environmental Regulation. Under a tax, or auctioned permits, firms gain area A but lose areas B and C. However, if firms are allocated permits equal to their equilibrium emissions, they gain A and D and lose only B.

Figure 3: French and German Contracts for Quarterly Baseload Electricity (e.g., fr0603 is French Quarter 3, 2006)

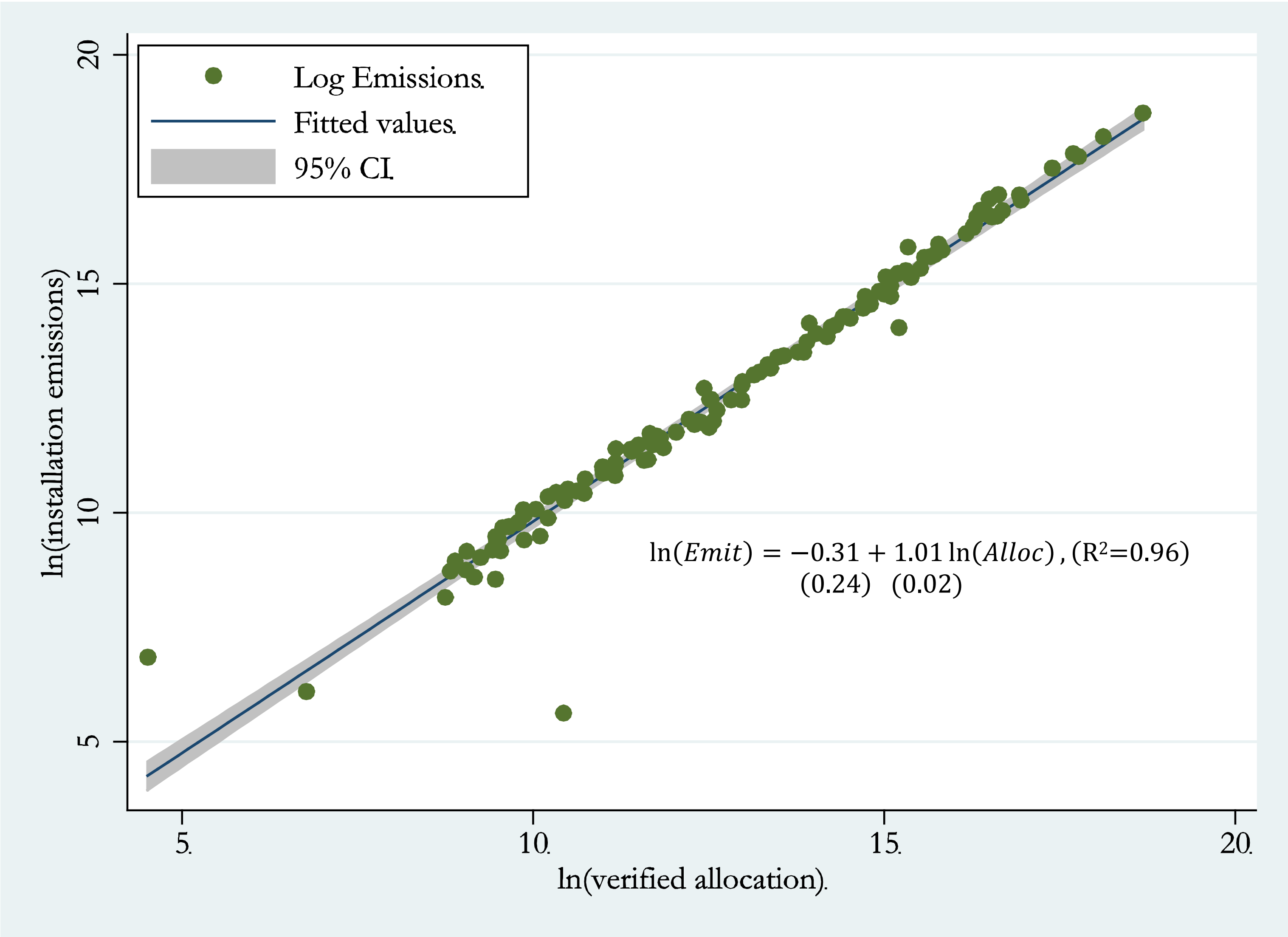


Figure 4: Most firms' allowances similar to emissions (Current subsample of 124 firms with emissions linked to stock market data)

Table 1: Stock Market Cumulative Returns by Industry

NACE	Industry Description	*Cum. Abnorm. Returns* Coef	S.E.		*Cumulative Returns* Coef	S.E.	
10	Coal and lignite mining	-0.032	(0.008)	***	-0.041	(0.001)	***
11	Crude petroleum extraction	-0.032	(0.009)	***	-0.044	(0.009)	***
13	Metal ores mining	-0.023	(0.017)		-0.041	(0.017)	**
14	Other mining	0.016	(0.000)	***	0.006	(0.000)	***
15	Food manufacturing	-0.003	(0.004)		-0.010	(0.004)	**
16	Tobacco manufacturing	-0.019	(0.004)	***	-0.025	(0.004)	***
18	Apparel manufacturing	0.002	(0.006)		-0.008	(0.006)	
19	Tanning leather	0.007	(0.000)	***	-0.002	(0.000)	***
21	Pulp and paper	-0.003	(0.007)		-0.013	(0.007)	*
22	Publishing and printing	-0.004	(0.005)		-0.011	(0.005)	**
23	Refining and coke	-0.027	(0.000)	***	-0.037	(0.000)	***
24	Chemicals	0.000	(0.006)		-0.010	(0.006)	
25	Rubber and plastics	-0.010	(0.008)		-0.022	(0.008)	***
26	Nonmetallic manufacturing	0.009	(0.009)		-0.001	(0.009)	
27	Basic metals	-0.031	(0.009)	***	-0.047	(0.009)	***
28	Fabricated metals	0.008	(0.012)		-0.004	(0.012)	
29	Machinery	0.000	(0.008)		-0.014	(0.008)	*
30	Computer manufacturing	-0.023	(0.003)	***	-0.034	(0.000)	***
31	Electrical machinery	-0.007	(0.006)		-0.021	(0.006)	***
32	Radio and TV	-0.008	(0.007)		-0.022	(0.007)	***
33	Medical instruments	-0.005	(0.008)		-0.015	(0.008)	*
34	Motor vehicles	-0.008	(0.008)		-0.020	(0.008)	***
35	Other transport	-0.009	(0.005)	*	-0.022	(0.005)	***
36	Furniture	0.003	(0.009)		-0.010	(0.009)	
40	Electricity and gas	-0.017	(0.006)	***	-0.026	(0.006)	***
41	Water	-0.016	(0.007)	**	-0.023	(0.007)	***
45	Construction	-0.006	(0.004)		-0.018	(0.004)	***
51	Wholesale trade	0.010	(0.008)		0.000	(0.008)	
52	Retail trade	-0.006	(0.003)	**	-0.014	(0.003)	***
55	Hotels and restaurants	-0.009	(0.005)	*	-0.017	(0.005)	***
60	Land transport	-0.011	(0.003)	***	-0.020	(0.003)	***
61	Water transport	-0.027	(0.008)	***	-0.035	(0.007)	***
62	Air transport	-0.003	(0.004)		-0.014	(0.004)	***
63	Supporting transport	0.014	(0.009)		0.004	(0.010)	
64	Post and telecomm	0.002	(0.005)		-0.006	(0.005)	
65	Financial intermediation	0.001	(0.003)		-0.009	(0.003)	***
66	Insurance	0.004	(0.003)		-0.008	(0.003)	**
67	Auxiliary financials	0.000	(0.004)		-0.013	(0.005)	***
70	Real estate	-0.016	(0.006)	***	-0.025	(0.006)	***
71	Renting machinery	0.022	(0.000)	***	0.009	(0.000)	***
72	Computer activities	-0.009	(0.005)	**	-0.022	(0.005)	***
74	Other business activities	-0.001	(0.003)		-0.012	(0.003)	***
85	Health and social work	0.007	(0.000)	***	-0.002	(0.000)	***
90	Sewage and refuse	-0.027	(0.000)	***	-0.033	(0.000)	***
92	Recreational and cultural	0.005	(0.007)		-0.003	(0.007)	
	All Industries	-0.005	(0.001)	***	-0.016	(0.001)	***

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 552 firms and 249,844 observations.

Table 2: Stock Market Cumulative Abnormal Returns for Firms in the Electricity Sector

Stock Name	Event	S.E.		Carbon per MWh	Carbon per Equity	MWh per Equity
Fortum	-0.088	(0.001)	***	0.214	0.265	1.236
Verbundgesellschaft	-0.086	(0.001)	***	0.252	0.941	3.729
British Energy Group	-0.071	(0.001)	***	0.108	1.117	10.365
EDF	-0.050	(0.001)	***	0.104	0.466	4.496
RWE (XET)	-0.045	(0.001)	***	0.909	3.049	3.355
Vestas Wind	-0.026	(0.001)	***			
A2A	-0.024	(0.001)	***	0.287	0.36	1.255
Atel Holding 'R'	-0.022	(0.001)	***	0.213		
DRAX Group	-0.019	(0.001)	***	1.046	3.854	3.684
EDP Energias de Portugal	-0.015	(0.001)	***	0.712	1.809	2.541
Solarworld	-0.013	(0.001)	***			
International Power	-0.012	(0.001)	***	0.611	2.084	3.414
E.ON	-0.007	(0.001)	***			
Red Electrica de Espana	-0.005	(0.001)	***	#		
Scot.& Southern Energy	-0.004	(0.001)	***	0.819	1.92	2.344
ENEL	-0.003	(0.001)	***	0.501	1.466	2.926
National Grid	-0.001	(0.001)	***	#		
Terna	-0.001	(0.001)	***	#		
Union Fenosa	0.004	(0.001)	***	0.972	1.265	1.301
Schneider Electric	0.011	(0.001)	***			
Iberdrola	0.015	(0.001)	***	0.349	0.451	1.291
Public Power	0.052	(0.001)	***	0.982	8	8.146

Notes: NACE 4011, plus other related firms (Atel Holding 'R', National Grid, and Schneider Electric). # denotes electricity transmission companies. Standard errors are robust.

Table 3: Tests of Net Permits at Firm Level

Panel A: All Industries (with NACE2 Fixed Effects)

	1	2		3		4
Net Permits	-1.11					
	(15.16)					
Allocation		4.12				5.82
		(2.93)				(16.37)
Emissions				3.95		-1.68
				(2.89)		(15.14)

Panel B: Industries Net Short in Permits (Power Industry Firms from Table 2)

	1	2		3		4
Net Permits	-7.29					
	(14.88)					
Allocation		7.84	***			6.70
		(1.45)				(12.24)
Emissions				7.65	***	1.12
				(1.52)		(12.59)

Panel C: Industries Net Long in Permits (with NACE2 Fixed Effects)

	1	2		3		4
Net Permits	2.79					
	(42.68)					
Allocation		-26.71	**			9.73
		(11.14)				(30.67)
Emissions				-30.63	***	-40.58
				(10.31)		(24.81)

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 55,894 observations (and 124 firms) in Panel A, 7480 (17) in Panel B, and 48,414 (107) in Panel C. Firms in the power industry had an average net short position of 2.78 million permits while firms in other industries were on average net long by 204 thousand.

Table 4: Summary Statistics by Industry

Industry	N	Event Return	Dirty Output	Dirty Input	Ave EU Exposure	Fraction Missing EE	Market Cap
Coal and lignite mining	2	-0.032	0.006	0.083	0.165	0.000	58,800
Crude petroleum extraction	20	-0.032	0.126	0.008	0.491	0.200	32,400
Basic metals	15	-0.031	0.416	0.039	0.565	0.067	10,500
Sewage and refuse	1	-0.027	0.000	0.011	1.000	0.000	2,910
Water transport	2	-0.027	0.000	0.002	#N/A	1.000	5,880
Refining and coke	2	-0.027	0.024	0.010	0.585	0.000	132,000
Computer manufacturing	2	-0.023	0.000	0.005	#N/A	1.000	3,830
Metal ores mining	7	-0.023	0.012	0.057	0.493	0.000	16,500
Tobacco manufacturing	3	-0.019	0.000	0.009	#N/A	1.000	26,600
Electricity and gas	26	-0.017	0.975	0.204	0.865	0.077	21,400
Real estate	16	-0.016	0.038	0.005	0.980	0.875	4,990
Water	4	-0.016	0.000	0.051	0.920	0.000	11,100
Land transport	5	-0.011	0.000	0.011	0.540	0.600	3,440
Rubber and plastics	3	-0.010	0.023	0.023	0.690	0.667	9,900
Computer activities	11	-0.009	0.005	0.003	0.665	0.818	10,300
Other transport	8	-0.009	0.001	0.009	0.423	0.125	12,100
Hotels and restaurants	9	-0.009	0.000	0.012	#N/A	1.000	6,790
Motor vehicles	11	-0.008	0.023	0.008	0.592	0.455	19,100
Radio and TV	12	-0.008	0.001	0.008	0.504	0.583	17,700
Electrical machinery	6	-0.007	0.001	0.012	0.506	0.167	25,200
Retail trade	19	-0.006	0.000	0.015	0.987	0.842	13,400
Construction	28	-0.006	0.010	0.002	0.726	0.357	6,900
Medical instruments	16	-0.005	0.002	0.006	0.483	0.529	6,550
Publishing and printing	8	-0.004	0.000	0.010	0.360	0.889	7,970
Air transport	5	-0.003	0.006	0.002	0.610	0.800	6,100
Pulp and paper	5	-0.003	0.143	0.044	0.773	0.200	7,550
Food manufacturing	20	-0.003	0.008	0.015	0.495	0.905	20,800
Other business activities	56	-0.001	0.105	0.004	0.742	0.536	20,200
Auxiliary financials	9	0.000	0.000	0.004	1.000	0.778	6,990
Machinery	18	0.000	0.002	0.010	0.490	0.111	7,410
Chemicals	38	0.000	0.020	0.023	0.544	0.342	24,200
Financial intermediation	53	0.001	0.000	0.003	0.836	0.833	20,600
Apparel manufacturing	5	0.002	0.000	0.008	#N/A	1.000	21,700
Post and telecomm	27	0.002	0.000	0.008	0.906	0.741	26,400
Furniture	3	0.003	0.000	0.010	0.460	0.333	12,100
Insurance	26	0.004	0.000	0.002	0.826	0.808	18,200
Recreational and cultural	11	0.005	0.023	0.010	#N/A	1.000	8,150
Health and social work	1	0.007	0.000	0.008	1.000	0.000	2,370
Tanning leather	1	0.007	0.000	0.009	0.420	0.000	10,500
Fabricated metals	6	0.008	0.010	0.015	0.663	0.000	6,060
Nonmetallic manufacturing	9	0.009	0.416	0.043	0.494	0.000	12,500
Wholesale trade	7	0.010	0.000	0.006	0.780	0.286	5,050
Supporting transport	10	0.014	0.088	0.006	0.816	0.300	7,080
Other mining	1	0.016	0.073	0.039	0.750	0.000	5,310
Renting machinery	1	0.022	0.000	0.004	0.590	0.000	1,450
All Industries	548	-0.005	0.087	0.020	0.655	0.529	16,600

Notes: The table reports the sample mean for each two-digit NACE sector. Dirty Output, Dirty Input, and EU Exposure are defined in the text. Market cap is equity value in millions of U.S. dollars on April 25, 2006.

Table 5: Heterogeneous Event Study by Industry Characteristics

	(1)	(2)	(3)	(4)	(5)	(6)
Event	-0.005***	-0.005***	-0.005***	-0.007**	-0.005*	-0.005*
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)
Dirty Output * Event		-0.017***			-0.008	
		(0.006)			(0.007)	
Dirty Input * Event			-0.080***			-0.054
			(0.019)			(0.045)
EU Exposure * Event				0.011	0.019*	0.017
				(0.013)	(0.011)	(0.012)
No EE * Event				0.003	0.000	0.001
				(0.003)	(0.002)	(0.002)
DO * EE * Event					-0.081***	
					(0.026)	
DO * NoEE * Event					-0.005	
					(0.012)	
DI * EE * Event						-0.238
						(0.162)
DI * NoEE * Event						0.044
						(0.051)

Notes: Firm fixed effects and firm-specific "betas" (coefficients on market returns) are not shown. The dependent variable is the daily percent change in a stock's price. Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are clustered by two-digit NACE codes. There are 552 firms and 249,844 observations.

Table 6: Robustness Results for Column 5 of Table 5

	(1) Main	(2) Big Event	(3) DE Ratio	(4) No CAPM	(5) No Elec
Event	-0.005*	-0.033***	-0.005**	-0.016***	-0.005*
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Dirty Output * Event	-0.008	-0.002	-0.007	-0.008	-0.012
	(0.007)	(0.013)	(0.007)	(0.008)	(0.017)
EU Exposure * Event	0.019*	0.031**	0.019*	0.023**	0.020*
	(0.011)	(0.014)	(0.011)	(0.011)	(0.011)
NoEE * Event	0.000	0.006	0.000	0.002	-0.003
	(0.002)	(0.005)	(0.002)	(0.002)	(0.003)
DO * EE * Event	-0.081***	-0.047	-0.081***	-0.074***	-0.104
	(0.026)	(0.033)	(0.026)	(0.027)	(0.062)
DO * NoEE * Event	-0.005	-0.036	-0.005	-0.002	-0.047
	(0.012)	(0.038)	(0.012)	(0.013)	(0.038)
Debt-Equity Ratio * Event			0.010		
			(0.024)		

Notes: See Table 5 for notes. Big event is defined as a 30-day window. DE ratio controls for the debt-equity ratio interacted with the event window. No CAPM excludes the firm "betas" from the regression. No Elec excludes electricity firms and has a sample of 528 firms and 239,172 observations.