NBER WORKING PAPER SERIES

PROFITING FROM REGULATION: AN EVENT STUDY OF THE EU CARBON MARKET

James B. Bushnell
Howard Chong
Erin T. Mansur

Working Paper 15572
http://www.nber.org/papers/w15572

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
December 2009

The authors are grateful for helpful discussion and comments from Antonio Bento, Denny Ellerman, Arik Levinsohn, Matt Kotchen, and seminar participants at Environmental Defense Fund, Georgetown, Harvard, Minnesota,UC Berkeley, UC Davis, UC Energy Institute, and Yale University. The views expressed herein are those of the author(s) and do not necessarily reflect the views of the National Bureau of Economic Research.

Profiting from Regulation: An Event Study of the EU Carbon Market
James B. Bushnell, Howard Chong, and Erin T. Mansur
NBER Working Paper No. 15572
December 2009
JEL No. G14,H22,H23,Q50,Q54

ABSTRACT

Tradable permit regulations have recently been implemented for climate change policy in many countries. One of the first mandatory markets was the EU Emission Trading System, whose first phase ran from 2005-07. Unlike taxes, permits expose firms to volatility in regulatory costs, but are typically accompanied by property rights in the form of grandfathered permits. In this paper, we examine the effect of this type of environmental regulation on profits. In particular, changes in permit prices affect: (1) the direct and indirect input costs, (2) output revenue, and (3) the carbon permit asset value. Depending on abatement costs, output price sensitivity, and permit allocation, these effects may vary considerably across industries and firms. We run an event study of the carbon price crash on April 25, 2006 by examining the daily stock returns for 90 stocks from carbon intensive industries and approximately 600 stocks in the broad EUROSTOXX index. In general, firms in industries that tended to be either carbon intensive, or electricity intensive, but not involved in international trade, were hurt by the decline in permit prices. In industries that were known to be net short of permits, the cleanest firms saw the largest declines in share value. In industries known to be long in permits, firms granted the largest allocations were most harmed.

James B. Bushnell
Department of Economics
468H Heady Hall
Iowa State University
Ames, IA 50011
and NBER
jimb@iastate.edu

Erin T. Mansur
Yale School of Management
135 Prospect Street
P.O. Box 208200
New Haven, CT 06520-8200
and NBER
erin.mansur@yale.edu

Howard Chong
UC Energy Institute
2547 Channing Way
Berkeley, CA 94720
HGChong@berkeley.edu

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 on the horizon 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 contingent upon a specific goals for GHG reductions, however, 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 credits. These credits 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 credits, 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 credits.

However, for most industrial enterprises, changes in direct abatement costs are only one piece of a complicated profitability puzzle. The introduction of a price of CO_2 into an economy can have indirect impacts on firms that are not large CO_2 emitters. In most

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

industries, increases in CO_2 costs 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 credits 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 credits proportionally to emissions, several papers have concluded that this likely amounts to overcompensation of the affected industries. These papers all use various simulation methodologies to forecast potential impacts of carbon taxes or caps. Bovenberg and Goulder (2001) and Goulder, et. al (2009) 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 European Union's Emissions Trading System (ETS) for CO_2. This is by far the most significant effort at regulating CO_2 emissions in the world. As a role model 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

[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.

allocation of emissions credits. During its first phase of operation from 2005 through 2007, the prices of emissions credits 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 subject to 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 effected 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, or electricity 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 international trade exposure, and find weak evidence that the benefits of higher CO_2 prices were concentrated amongst sectors with little exposure to international trade.

In section 2, we develop a simple model of the impacts of CO_2 costs on firm profitability in order to illustrate the potential impacts. In section 3, 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 4, we examine the underlying elements of firm characteristics that influenced the response to the change in CO_2 prices. We conclude in section 5.

2 Emissions Regulations and Firm Profits

In this section we develop 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. Consider a firm producing products for a market represented by the demand curve $P(Q)$, where Q represents total industry production 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 and its total production q. We assume that the production technology determines the emissions rate, $r(q)$ and that this rate cannot be changed over the time horizon we are considering. The per-unit price of emissions permits is τ, resulting in direct compliance costs of τrq, however the firm may also receive a free allocation of emissions credits A. Considering both input and environmental costs, the net profits of this firm can be represented as

$$\pi = P(Q) * q - C(q, \omega) + \tau A - \tau rq$$

where the function $C(q, \omega)$ represents the total cost of producing q with a vector of input costs w. The impact of a change in the permit price τ can be expressed as

$$\frac{\partial \pi}{\partial \tau} = P * \frac{\partial q}{\partial \tau} + P' \frac{\partial Q}{\partial \tau} * q - \frac{\partial C}{\partial \tau} + A - rq - \frac{\partial r}{\partial \tau}\tau \tag{1}$$

where for notational brevity we have combined the input price and output adjustments of a permit price shock above. In other words

$$\frac{\partial C}{\partial \tau} = \frac{\partial C}{\partial \omega}\frac{\partial \omega}{\partial \tau} + \frac{\partial C}{\partial q}\frac{\partial q}{\partial \tau}$$

and

$$\frac{\partial r}{\partial \tau} = r' * \frac{\partial q}{\partial \tau}$$

For firms with market power in their product market, we can also consider the effect on product prices to be a combination of changes in their own output and the output of other firms. In other words, for firm i

$$P'\frac{\partial Q}{\partial \tau} = P' * \left(\frac{\partial q_{\neq i}}{\partial \tau} + \frac{\partial q_i}{\partial \tau}\right)$$

where q_i is the output of firm i and $q_{\neq i}$ is the output of all other firms, and therefore $Q = q_i + q_{\neq i}$.

If we simplify the responses of firms further by assuming that emissions rates r are constant, we can further reduce equation 1 to

$$\frac{\partial \pi}{\partial \tau} = P * \frac{\partial q}{\partial \tau} + P'\frac{\partial Q}{\partial \tau} * q - \frac{\partial C}{\partial \tau} + A - rq$$

for shocks that have marginal influence on the output of firm i, the envelope theorem would imply that

$$\left(P + P'\frac{\partial q_i}{\partial \tau} * q_i - \frac{\partial C}{\partial q} - r\tau\right)\frac{\partial q_i}{\partial \tau} = 0 \tag{2}$$

In other words, the change in profitability from changing own output levels would be negligible. However, there are still effects relating to direct costs, the value of ones endowment of permits, and changes in market prices due to the responses of other firms in the industry. Removing the terms from 2 from equation 1 we are left with

$$\frac{\partial \pi_i}{\partial \tau} = P'\frac{\partial q_{\neq i}}{\partial \tau} * q_i - \frac{\partial C}{\partial \omega}\frac{\partial \omega}{\partial \tau} + A - rq_i \tag{3}$$

The individual terms in equation 3 illustrate the competing potential effects of a change in the permit price. First, revenues may increase due to the fact that other firms in the industry have collectively responded by reducing output. This is similar to a "raising rivals' costs" effect.[3] Under the assumption that firms would reduce output in the face of

[3] Salop and Scheffman, 1983

an increase in permit costs, this term would be positive. Second, the middle term on the right hand side of (3) captures the impact of changes in input costs due to a change in the permit price. To the extent that these inputs (*e.g.* electricity) come from industries that are themselves subject to the environmental regulation, this term would presumably be negative. The last term, $A - rq$ reflects the change in direct compliance costs of a change in permit prices. If a firm is "short" in permits, then $A < rq$ and this term would be negative.

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).

In the following sections, we will examine each of these potential effects empirically. The relative magnitudes of these effects will largely depend upon three key factors, the elasticity of demand for the firm's product, the firm's endowment of permits, and the relationship between a firm's marginal cost and its average cost with respect to emissions and other input prices. Figure 1 helps to illustrate these factors. We assume here that a firm faces a residual demand curve D, and has a marginal cost function $c_{\tau 1}$ before the imposition, or increase, in permit prices. In this we figure, we also assume that the demand curve D is unaffected by a change in permit prices, one condition for which is that the firm faces competition from outside the capped region.

The classic analysis of the incidence of taxation on such a firm would imply 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 production quantities.

If true the producer surplus is clearly reduced from the sum of areas B and C to the area A in figure 1a. The allocation of revenues collected, or of permits, would then be critical in determining the net effect of the regulation. If the firm received a free allocation equivalent to 100% of its ex-post emissions, this would be a transfer equivalent to the areas C and D, which totally offsets the increased regulatory cost. As long as the demand for product is sufficiently inelastic, the firm's net profit improves because its revenue increases without any increase in environmental costs. Indeed as Bovenberg and Goulder (2001) demonstrate, only a relatively small allocation of emissions credits is necessary to fully compensate many industries for changes in profits due to CO_2 costs.

However, even without an allocation of emissions, 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 industries. Consider a case where emissions rates are increasing with production quantities, as illustrated in figure 1b. The increase in permit costs now raises 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, even larger, effect could arise if an individual firm happens to have a "cleaner" technology than its rivals. Such a circumstance would have the effect of decreasing the residual elasticity of demand for the clean firm. Again product prices could rise much faster than average production costs.

Of course, such an effect strongly depends upon the fact that much of the incidence of increased emissions costs are being passed on to consumers. If the firm in question were instead faced with very elastic demand for its product, even a substantial convexity in the marginal cost curve could not compensate for the fact that the producer is absorbing the bulk of the emissions cost increase (figure 1c).

This discussion is meant to illustrate the varied potential effects and emphasize the importance of several important industry characteristics in determining the net effects of environmental regulations. In the following section, 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 The EU Emissions Trading System

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 effected industries in these countries, particularly in the power sector, were allocated less permits than their observed observations and 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, most notably 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 outstripped measured emissions by about 2.8% of the total available. 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 credits 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.[4] 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.

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

3.1 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 through March 2006, prices rose steadily to over 30 Euro/ton. 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.[5] 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 uncertainty about price levels. This changed 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 2, the reaction was dramatic. Over the next few days, the permit price as reported on the European Climate Exchange fell from 28 Euros/ton on April 25 to 14 Euros/ton 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. In fact, the surpluses reported during those periods were not reflective of the more modest surplus left at the end of phase I, and even these initial reports were revised shortly after they were made public. By May 15, when the final emissions totals were officially released, phase I prices had rebounded and then

[5] Joskow and Ellerman, 2008.

fallen slightly again to settle around 16 Euros/ton.

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 Euros/ton.

3.2 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) (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, Veith, et al., find that share prices of "clean" electricity producers not covered under the ETS had no significant response to CO_2 prices.

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 effected, however, and we focus our attention on these firms. We employ a standard event-study approach.[6] We examine firms contained in the Dow Jones STOXX

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

600 index, which is similar to the S&P 500 but covers European firms.[7] 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 (2009). 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 here 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 extraordinary returns during this event window.

$$\ln(S_{i,t}/S_{i,t-1}) = \alpha_i + \beta_i \ln(M_t/M_{t-1}) + \gamma_i EVENT_t + \epsilon_{i,t} \tag{4}$$

where $S_{i,t}$ is the share price of firm i and M_t is the price of the market index at time t, 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 GAMMA represents the cumulative excess return during the event window.

We run regression (4) for each stock in the index individually, and aggregate individual γ_i to summarize results by industry categories. We perform this aggregation through the following regression.

$$\widehat{\gamma}_i = \theta_j + \varepsilon_i \ \forall \ i \in j. \tag{5}$$

[7] 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.

Industrial categories j are based upon NAICS 2 digit classifications.[8] Intuitively, the coefficient value θ_j therefore represents the average effect of all firm specific impacts within each industry sector.

Table 1 summarizes the event effects by industrial classification. Many of the largest significant declines were registered in industries that feature prominently in the EU ETS, including Mining and Oil & Gas Extraction and Utilities. However, there are also notable declines in such industries as Real Estate. Accommodation & Food Services, and Construction. As we describe below, each of these industries are relatively large users of electricity and sell to relatively local markets. The largest increase was in Wholesale Trade.

These results are merely meant to summarize general effects. The groupings in Table 1 are somewhat problematic, as classifications can be imperfect and there can be considerable heterogeneity of firms within a classification. This latter 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 a firm, as is more easily done within the electricity sector, some suggestive patterns begin to emerge. In general, 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.

[8] These data are provided by Compustat. Thompsons Datastream provides a classification called INDM which provides similar results as the 2-digit NAICS, but NAICS was chosen because it is more widely used in the literature and because it is more easily linked to other industrial characteristics discussed below. However, Weiner (2005) evaluates several industrial classification schemes and finds drawbacks in each.

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 significantly 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 this section, we examine which industry and firm characteristics determine the profitability of some firms in the face of CO_2 price changes. First we test the importance of firms' allocation of permits, net of emissions, in determining abnormal returns. Then we test whether the share price changes described in the previous section are consistent with a "revenue effect."

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 90 publicly-traded firms in the largest sectors regulated by the ETS. 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 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:

$$\widehat{\gamma}_{ij} = \theta_j + \mu(A_i - E_i)/M_i + \eta_{ij}, \tag{6}$$

where A_i be the historic 2005 allocation, E_i be historic 2005 emissions (as measured in the spring of 2006), and M_i is the firm's historic market cap in thousands of Euros (*e.g.*, on April 25, 2006). In order to control for industry average differences, we examine including 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 $(A - E)$ should be considered only proxies for the "true" net position of firms at the time of the event. Importantly, the broader market also did not know these "true" net position, 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 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 and then scaled for the thousand euro denominator, or about -42. A firm with, say, 1 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 15 Euros per tonne. Hence, this hypothetical firm would have lost, 1 million tons/year * 3 years * -14 Euro, or 42 million Euros.

Table 3 reports the results. We find that the coefficient on net position is statistically significantly different from -42. In fact, we do not even find a statistically significant coefficient. In Panel A, we exclude fixed effects and find a coefficient of -6.9 that is insignificant. Even after controlling for industry fixed effects, in Panels B and C, we find a very similar result (negative and insignificant).

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 3, which plots the 90 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 initial allocation explain over 95 percent of the variation in 2005 emissions.

In Table 3, we next examine whether the abnormal returns were correlated with a firm's level of emissions, or allocations. We find no evidence of this in Panel A. However, the picture becomes more clear once we control 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 on net short of permits. 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.

With industry fixed effects 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 6.25 Euros. Firms with higher allocations also had better returns, but recall that emissions and allocations are almost completely co-linear, so this is likely also an emissions effect. 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 ton of allocation implying a reduction of 31.5 Euros 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.

4.2 Tests of Revenue Effects

Recall from Section 2 that the revenue effect depends on how a cost shock in an industry affects the output prices, $\partial p/\partial\tau$. This in turn will depend upon the elasticity of demand for the product, the convexity of a firm's costs with respect to emissions costs, and the relative emissions of other firms in the industry. For example, industries that have little international trade exposure, use many dirty inputs, and produce substantial carbon emissions are more likely to have a strong revenue effect. In order to test the importance of these factors, we examine the abnormal returns during the event window as estimated in equation 4, $\widehat{\gamma}_i$.

$$\begin{aligned}\widehat{\gamma}_{ij} &= \delta_0 + \delta_1 1(DO_j > 0) + \delta_2 DO_j + \delta_3 1(DI_j > 0) \\ &\quad + \delta_4 DI_j + \delta_5 1(TE_j > 0) + \delta_6 TE_j + \nu_{ij},\end{aligned} \tag{7}$$

where DO_j is a measure of how dirty (carbon intensive) is an industry's output, DI_j is a measure of how dirty are an industry's inputs, and TE_j measures the trade exposure of the industry. We describe each of these variables in more detail below.

Sectors were characterized by the "dirty output," "dirty input," and "trade exposure" variables at the NAICS 3-digit level. Dirty output (DO) comes from combining CITL emissions data with Thomson's Datastream financial data. For all sectors j where at least one firm was matched in the CITL, DO is given by the following formula.

$$DO_j = \frac{\sum_{i \in (j \cap CITL)} Emit_i}{\sum_{firm \in (j \cap CITL)} S_i} \tag{8}$$

where $Emit_i$ is the sum of facility level emissions in the CITL over all facilities owned by firm i and S_i is the 2005 revenue of firm i. The subscript j indexes NAICS3 sectors, and $CITL$ indexes firms contained in the CITL emissions data set. The emissions factor calculated above is then normalized to the 0-1 range. Emissions intensity for *any* firm in a given NAICS sector will therefore be based upon the measured emissions of firms matched with CITL data in that NAICS sector. There were 90 firms for whom we have been able to match with the facility level emissions data, and 202 firms contained in the STOXX 600 index drawn from the sectors for which we have matched emissions data.

Dirty input comes from input output tables of industrial activity. DI_j is the direct plus indirect input use of the electricity sector in producing one dollar of output in sector N. We are not aware of sources of input output tables for the EU with NAICS nomenclature, so the index here is calculated using US figures from the Bureau of Economic Analysis (BEA). As with DO, we normalize the value of DI to range between 0 and 1.

Trade Exposure (TE) is a measure of how much a given commodity is internationally traded. We use a measure of Trade Exposure that the European Union has proposed to be used in determining which sectors get free allocation due to industrial competitiveness concerns.[9]

[9] Convery, *et al.*, 2008

$$TE_j = \frac{(EXPORT_j + IMPORTS_j)}{(OUTPUT_j + IMPORTS_j)}$$

$EXPORTS$ and $IMPORTS$ are with respect to the EU region, so intra-EU trade (which is uniformly under the ETS) is not counted. US trade (from COMTRADE) and production (from BEA) data was used to construct these measures. Though European data is preferable, US data should be equivalent if US and European input output tables and trade profiles are similar. US data was used because it was already coded to NAICS, whereas European data is coded in NACE codes, which require further (imperfect) translation to NAICS via correspondence tables.

Table 4 provides the summary statistics for twenty sectors (based on two-digit NAICS codes). For each sector, the table reports average abnormal returns during the event window. In addition, the sectors' industry characteristics (DO_j, DI_j, and TE_j) as well as the market capitalization are summarized. The mining, oil and natural gas extraction sector is that which is most electricity intensive: it had the largest average abnormal stock drop of approximately 2.7 percent. Utilities have the highest carbon emissions intensity: its average stocks had an abnormal decline of about 1.8 percent.

Note that for each of these variables there are many sectors with no value. For DO this is because many industries are not covered under the cap and trade system. In the sample of 600 firms, roughly 40% are in industries covered by the ETS and therefore have non-zero values for DO. In the case of DI, there are some (roughly five percent) firms with NAICS codes not contained in the BEA input-output tables. In the case of trade exposure, this is an artifact of our reliance on trade and production data. These data are focused on the manufacturing sectors, and therefore several industries, particularly service oriented ones, are not considered to be involved in international trade. About 60% of the 600 firms have no value for trade exposure. It is because of these issues that we include dummy variables that are applied to all firms with non-zero values for DO, DI, and TE respectively in the specification described above.

Table 5 reports the results of different variations of regression 7. The first two columns report the results controlling only for dirty output, or dirty input respectively. The third column controls only for trade exposure. The fourth and fifth columns interact DI and DO with trade exposure, under the intuition that trade exposure should matter less in relatively "clean" industries that are unaffected by CO_2 prices. Column seven combines all these variables by interacting both DO and DI with trade exposure.

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 usage) saw their share prices decline. This is suggestive of a revenue effect, as firms in these industries will have experienced a decline in their competitor's, as well as their own, marginal costs. When DI is interacted with trade exposure, the coefficient on DI roughly doubles, suggesting that it was firms with no trade exposure who are largely driving the negative value on DI. The interaction term on DI and TE is positive, but very imprecisely estimated. When all terms are considered simultaneously, higher values of both DO and DI significantly impact a decline in share prices during the event.

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. Keep in mind that these 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.

We examine the robustness of these results in several ways. One question is the appropriate time window for the event. This is particularly true as the volatility in permit prices continued beyond the 3 day window examined above. To address this question we also exam a 30 day event window we call $BIGEVENT$, consisting of 5 days prior and 25 days after April 25, 2006. We generate new $\widehat{\gamma}_i$ estimates using the $BIGEVENT$ window and perform the same analysis on the influences on share price performance. Table 6 describes the results for these regressions. As before, both DI and DO produce negative, although insignificant, coefficients when considered on their own. When all factors are included (column 7), the coefficients for dirty inputs and dirty outputs are negative and significant at the 10% level. Interestingly, the impacts of trade exposure are much stronger than during the shorter event window. While firms with trade exposure in general saw a decline in shares, the interaction terms for both DO and DI are positive and at least weakly significant. This indicates that although dirty firms saw a decline in shares overall, the dirtiest firms that were most exposed to international trade benefitted from the CO_2 price decline.

In Table 7, we add a measure of the firm's debt-to-equity ratio. Note that the net present value of all future profits equal 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 factor, it does not change the underlying picture with regards to dirty inputs and outputs during the short event window. In Table 8, we test the importance of the CAPM framework to the results by testing the event on the unadjusted returns (e.g. no β term) of the shares. The results are very similar to those of table 5.

In Table 9, we test for the presence of possible spillovers to a neighboring market by performing a similar analysis for the stocks in the US Standard and Poors 500 index. When all factors are considered, the only variable of significant impact on returns is the DO index variable, which is positive, indicating that dirty firms experienced an increase during this period. Since many of these firms are drawn from industries with "local" markets, such as utilities, this could be interpreted as implying a negligible spillover effect on firms in the US. In Table 10 we 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.

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 has ranged up to 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. It a desire to examine this full portfolio of impacts that 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 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 effected 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.

References

[1] Becker, Randy A. and J. Vernon Henderson. 2000. "Effects of Air Quality Regulations on Polluting Industries." *Journal of Political Economy*, 108: 379-421.

[2] Betz, R., W. Eichhammer, and J. Schleich. 2004. "Designing National Allocation Plans for EU-Emissions Trading- A First Analysis of the Outcomes." *Energy & Environment*, 15(3): 375-426.

[3] Bovenberg, A. Lans, and Lawrence H. Goulder, 2001. "Neutralizing the Adverse Industry Impacts of CO_2 Abatement Policies: What Does It Cost?" in *Behavioral and Distributional Effects of Environmental Policy.* C. Carraro and G. Metcalf ed. Chicago: University of Chicago Press, pp. 45- 85.

[4] Brown, S.J., and J. Warner. 1985. "Using Daily Stock Returns: The Case of Event Studies." *Journal of Financial Economics,* 14(1): 3-31.

[5] Burtraw, Dallas, and Karen Palmer. 2008. "Compensation Rules for Climate Policy in the Electricity Sector." *Journal of Policy Analysis and Management,* 27(4): 819-847.

[6] Convery, Frank, Denny Ellerman, and Christian De Perthuis. 2008. "The European Carbon Market in Action: Lessons from the First Trading Period." Report 158. MIT Joint Program on the Science and Policy of Global Change.

[7] Delarue, E., K. Voorspools, and W. D'haeseleer. 2008. "Fuel Switching in the electricity sector under the EU ETS," *Journal of Energy Engineering-Asce.* 134: 40-46.

[8] Ellerman, Denny, and Paul Joskow. 2008. "The European Union's Emissions Trading System in Perspective." Pew Center for Global Climate Change. May.

[9] Ellerman, Denny, Paul Joskow, Richard Schmalensee, Juan-Pablo Montero, and Elizabeth M. Bailey. 2000. *Markets for Clean Air: The U.S. Acid Rain Program.* Cambridge University Press.

[10] Goulder, Lawrence, H., Hafstead, Marc, A.C., and Michael Dworsky. 2009 "Impacts of Alternative Emissions Allowance Allocation Methods Under a Federal Cap-and-Trade Program." Stanford University Working Paper.

[11] Gray, Wayne B. 1987. "The Cost of Regulation: OSHA, EPA and the Productivity Slowdown," *American Economic Review*, 77: 998-1006.

[12] Gray, Wayne, and Ronald Shadbegian. 2003. "Environmental Regulation, Investment Timing, and Technology Choice." *Journal of Industrial Economics,* 46(2): 235-256.

[13] Greenstone, Michael. 2002. "The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures." *Journal of Political Economy*, 110(6): 1175-1219.

[14] Kahn, Shulamit , and Christopher R. Knittel (2002). "The impact of the clean air act amendments of 1990 on electric utilities and coal mines: evidence from the stock market," working paper CSEMWP-118, University of California Energy Institute, 2002.

[15] Kettner, C., A. Köppl, S.P. Schleicher, and G. Thenius. 2008. "Stringency and Distribution in the EU Emissions Trading Scheme: First Evidence." *Climate Policy,* 8(1): 41-61.

[16] Linn, Joshua (2006), "Stock prices and the cost of environmental regulation", AEI-Brookings Related Publication 06-16, 2006.

[17] Linn, Joshua. (2009). "The effect of cap-and-trade programs on firms profits: Evidence from the Nitrogen Oxides Budget Trading Program," Journal of Environmental Economics and Management.

[18] List, John A., Daniel L. Millimet, Per G. Fredriksson, and W. Warren McHone. 2003. "Effects of Environmental Regulations on Manufacturing Plant Births: Evidence from

a Propensity Score Matching Estimator," *Review of Economics and Statistics*, 85(4): 944-952.

[19] List, John A., Daniel L. Millimet, and Warren McHone. 2004. "The Unintended Disincentives in the Clean Air Act." *Advances in Economic Analysis & Policy*, 4(2).

[20] MacKinlay, A.C. 1997. "Event Studies in Economics and Finance." *Journal of Economic Literature,* 25(1): 13-39.

[21] Oberndorfer, Ulrich. (2009). "EU Emission Allowances and the stock market: Evidence from the electricity industry," *Ecological Economics*. 68: 1116-1126.

[22] Puller, Steven L. (2006). "The strategic use of innovation to influence regulatory standards." *Journal of Environmental Economics and Management*. 52: 690Ð706

[23] Ryan, Stephen. (2007). "The Costs of Environmental Regulation in a Concentrated Industry." MIT Working Paper.

[24] Seade, Jay. (1985). "Profitable Cost Increases and the Shifting of Taxation: Equilibrium Responses of Markets in Oligopoly." University of Warwick Working Paper.

[25] Sijm, J.P.M., K. Neuhoff, Y. Chen. 2006. "CO_2 cost pass-through and windfall profits in the power sector." *Climate Policy,* 6(1): 49-72.

[26] Smale, R., M. Hartley, C. Hepburn, J. Ward, and M. Grubb. 2006. "The impact of CO_2 emissions trading on firm profits and market prices." *Climate Policy,* 6(1): 31-48.

[27] Veith, Stefan, Joerg Werner, and Jochen Zimmermann. 2009. "Economic Consequences of Emission Trading Schemes: Evidence from the European Power Sector." *Energy Economics*, 31(4): 605-613.

Figures and Tables

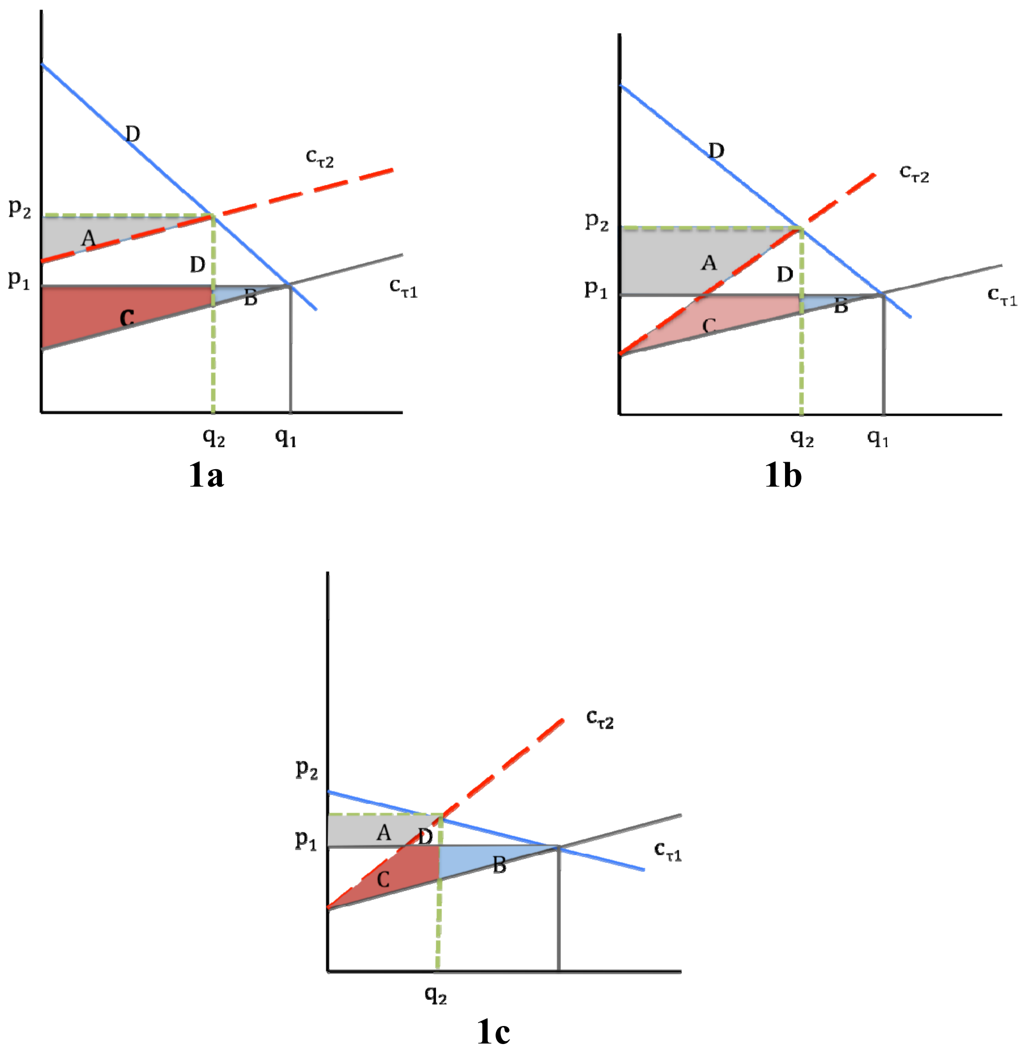

Figure 1: Theoretical Change in Producer Surplus under Environmental Regulation. Under a tax, or auctioned permits, firms gain area A but lose areas B and C. However, if firms are allocated permits equal to their equilibrium emissions, they gain A and D and lose only B.

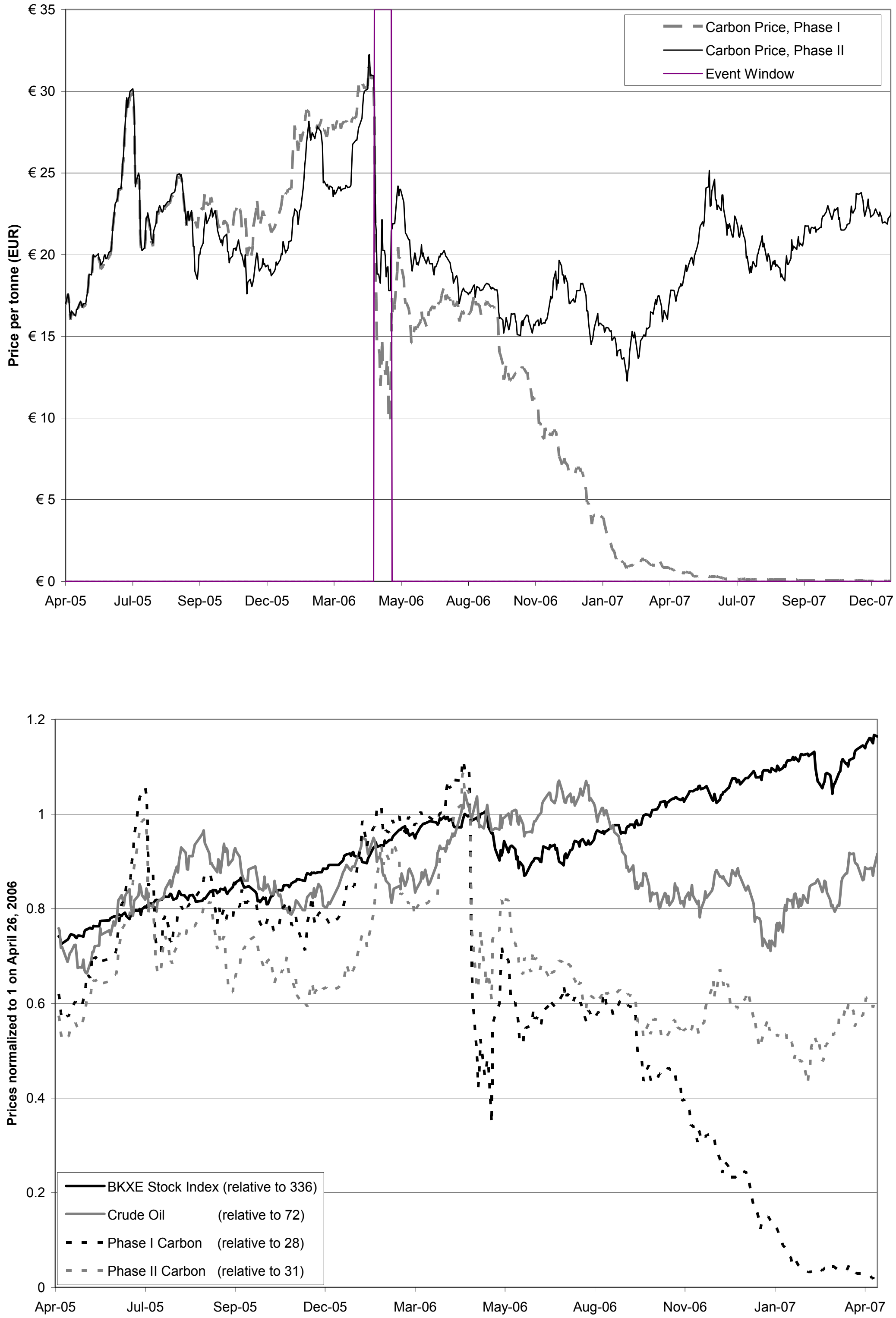

Figure 2: EU Carbon Prices, Stock Index, and Oil Prices

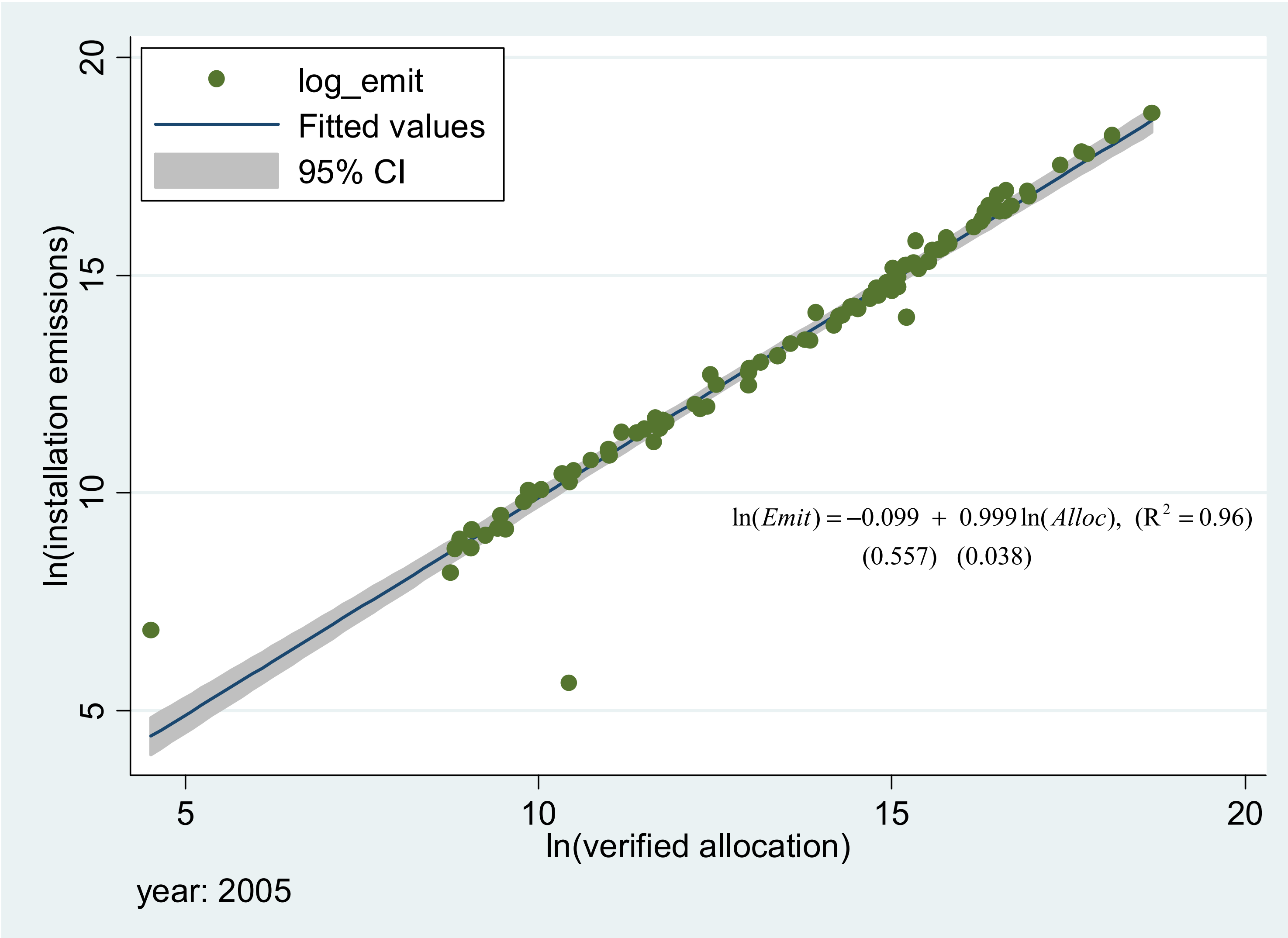

Figure 3: Most firms' allowances similar to emissions (Current subsample of 90 firms with emissions linked to stock market data)

Table 1: Stock Market Cumulative Returns by Industry

NAICS	Sector	*Cumulative Abnormal Returns* Coef.	Std. Err.	*Cumulative Returns* Coef.	Std. Err.
21	Mining & Oil/Gas Extraction	-0.0273	(0.0070)***	-0.0358	(0.0069)***
22	Utilities	-0.0179	(0.0000)***	-0.0211	(0.0001)***
53	Real Estate & Rental	-0.0132	(0.0024)***	-0.0169	(0.0023)***
23	Construction	-0.0115	(0.0034)***	-0.0188	(0.0033)***
72	Accommodation & Food Services	-0.0081	(0.0064)	-0.0117	(0.0058)**
33	Manufacturing (Metals, Machinery)	-0.0068	(0.0031)**	-0.0143	(0.0033)***
45	Retail (General, Misc)	-0.0059	(0.0010)***	-0.0098	(0.0001)***
31	Food & Textiles	-0.0053	(0.0014)***	-0.0096	(0.0015)***
54	Professional, Scientific, & Technical Services	-0.0052	(0.0000)***	-0.0119	(0.0000)***
32	Manufacturing (Paper, Plastics)	-0.0032	(0.0031)	-0.0092	(0.0037)**
99	Other	-0.0016	(0.0088)	-0.0083	(0.0094)
48	Transportation	-0.0001	(0.0049)	-0.0052	(0.0051)
51	Information	0.0002	(0.0035)	-0.0067	(0.0037)*
52	Finance & Insurance	0.0008	(0.0008)	-0.0061	(0.0008)***
44	Retail (Electronics, Gas, Health)	0.0019	(0.0070)	-0.0043	(0.0059)
71	Arts, Entertainment, & Recreation	0.0043	(0.0101)	-0.0011	(0.0099)
62	Health Care & Social Assistance	0.0110	(0.0030)***	0.0059	(0.0031)*
56	Administrative & Support	0.0130	(0.0000)***	0.0048	(0.0000)***
49	Couriers & Storage	0.0139	(0.0064)**	0.0090	(0.0072)
42	Wholesale Trade	0.0166	(0.0052)***	0.0098	(0.0058)*
	All Sectors	-0.0045	(0.0015)***	-0.0202	(0.0026)***

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 572 observations. Industry is by NAICS.

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

Panel A. Firm Level Cumulative Abnormal Returns

Stock Name	Event	Carbon per MWh	Carbon per Equity	MWh per Equity
Fortum	-0.088	0.214	0.265	1.236
Verbundgesellschaft	-0.086	0.252	0.941	3.729
British Energy Group	-0.071	0.108	1.117	10.365
EDF	-0.050	0.104	0.466	4.496
RWE (XET)	-0.045	0.909	3.049	3.355
A2A	-0.024	0.287	0.360	1.255
Atel Holding 'R'	-0.022	0.213		
DRAX Group	-0.019	1.046	3.854	3.684
United Utilities Group	-0.018			
EDP Energias de Portugal	-0.015	0.712	1.809	2.541
International Power	-0.012	0.611	2.084	3.414
Red Electrica de Espana	-0.005			
Scot.& Southern Energy	-0.004	0.819	1.920	2.344
ENEL	-0.003	0.501	1.466	2.926
National Grid	-0.001			
Terna	-0.001			
Union Fenosa	0.004	0.972	1.265	1.301
Schneider Electric	0.011			
Iberdrola	0.015	0.349	0.451	1.291
Public Power	0.052	0.982	8.000	8.146

Panel B. Correlations

	Event	*Carbon per MWh*	*Carbon per Equity*
Carbon per MWh	0.593	1.000	
Carbon per Equity	0.580	0.689	1.000
MWh per Equity	-0.035	-0.091	0.476

Notes: NAICS 2211

Table 3: Tests of Net Permits at Firm Level

Panel A: All Industries (with NAICS3 Fixed Effects)

	1	2	3	4
Net Permits	-6.90			
	(7.18)			
Allocation		4.17		0.26
		(3.57)		(14.15)
Emissions			4.10	3.85
			(3.22)	(10.90)
Constant	F.E.	F.E.	F.E.	F.E.

Panel B: Industries Net Short in Permits (Power Industry)

	1	2	3	4
Net Permits	-1.51			
	(11.44)			
Allocation		6.65***		16.35
		(1.32)		(11.28)
Emissions			6.25***	-9.45
			(1.50)	(11.14)
Constant	-0.022**	-0.031***	-0.031***	-0.030***
	(0.008)	(0.007)	(0.008)	(0.008)

Panel C: Industries Net Long in Permits (with NAICS3 Fixed Effects)

	1	2	3	4
Net Permits	-17.11			
	(29.18)			
Allocation		-31.53***		-6.73
		(6.81)		(20.24)
Emissions			-34.56***	-27.64
			(6.79)	(17.58)
Constant	F.E.	F.E.	F.E.	F.E.

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 90 observations in Panel A, 21 in Panel B, and 69 in Panel C. Firms in the power industry had an average net short position of 2.15 million while firms in other industries were on average net long by 282 thousand.

Table 4: Summary Statistics

Sector	N	Event Return	Dirty Output	Dirty Input	Trade Exposure	Market Cap
Mining & Oil/Gas Extraction	23	-2.73%	0.08	0.39	0.58	15,400,000,000
Utilities	28	-1.79%	0.97	0.04	n/a	18,900,000,000
Real Estate & Rental	21	-1.32%	n/a	0.14	n/a	4,870,000,000
Construction	28	-1.15%	0.00	0.10	n/a	6,680,000,000
Accommodation & Food Services	8	-0.81%	n/a	0.24	n/a	7,050,000,000
Manufacturing (Metals, Machinery)	100	-0.68%	0.05	0.22	0.52	9,950,000,000
Retail (General, Misc)	5	-0.59%	n/a	n/a	n/a	27,500,000,000
Food & Textiles	34	-0.53%	n/a	0.24	0.26	18,800,000,000
Professional, Scientific, & Technical Services	21	-0.52%	0.00	0.03	n/a	4,270,000,000
Manufacturing (Paper, Plastics)	65	-0.32%	0.10	0.30	0.35	30,100,000,000
Other	7	-0.16%	0.35	n/a	n/a	31,900,000,000
Transportation	23	-0.01%	0.03	0.09	n/a	6,610,000,000
Information	47	0.02%	n/a	0.05	n/a	18,600,000,000
Finance & Insurance	121	0.08%	n/a	0.01	n/a	22,100,000,000
Retail (Electronics, Gas, Health)	16	0.19%	0.09	n/a	n/a	11,900,000,000
Arts, Entertainment, & Recreation	4	0.43%	n/a	0.22	n/a	6,140,000,000
Health Care & Social Assistance	2	1.10%	n/a	0.09	n/a	6,830,000,000
Administrative & Support	8	1.30%	n/a	0.03	n/a	5,530,000,000
Couriers & Storage	3	1.39%	n/a	0.13	n/a	16,600,000,000
Wholesale Trade	8	1.66%	n/a	0.05	n/a	5,050,000,000

Notes: The table reports the sample mean for each two digit NAICS sector. Dirty Output is ratio of industry's emissions share to industry's equity share, Dirty Input is electricity costs over sales, Trade exposure is the ratio of the sum of imports and exports over the sum of imports and sales, and market cap is equity value in $1000s.

Table 5: Tests of Revenue Effects at Industry Level

	1	2	3	4	5	6	7
Dirty Output Indicator		-0.0033				-0.0015	-0.0003
		(0.0029)				(0.0026)	(0.0023)
DO Index		-0.0126***				-0.0138***	-0.0149***
		(0.0031)				(0.0036)	(0.0040)
Dirty Input Indicator			-0.0010		-0.0002		-0.0004
			(0.0044)		(0.0046)		(0.0046)
DI Index			-0.0236**		-0.0527**		-0.0535*
			(0.0107)		(0.0252)		(0.0272)
Trade Exposure Indicator				-0.0047	0.0068	-0.0045	0.0066
				(0.0039)	(0.0058)	(0.0039)	(0.0060)
Trade Index				0.0030	-0.0104	0.0044	-0.0121
				(0.0041)	(0.0120)	(0.0067)	(0.0121)
DI*Trade Index					0.0507		0.0585
					(0.0436)		(0.0512)
DO*Trade Index						-0.0282	-0.0098
						(0.0272)	(0.0323)
Constant	-0.0029*	-0.0007	0.0012	-0.0016	0.0012	-0.0001	0.0028
	(0.0016)	(0.0017)	(0.0040)	(0.0021)	(0.0040)	(0.0019)	(0.0044)

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 572 observations. Industry is by NAICS.

Table 6: Robustness to Big Event Window

	1	2	3	4	5	6	7
Dirty Output Indicator		-0.0034				0.0036	0.0027
		(0.0074)				(0.0075)	(0.0072)
DO Index		-0.0120*				-0.0210**	-0.0203**
		(0.0067)				(0.0080)	(0.0079)
Dirty Input Indicator			-0.0227		-0.0156		-0.0153
			(0.0174)		(0.0175)		(0.0167)
DI Index			-0.0139		-0.0977**		-0.1012**
			(0.0169)		(0.0469)		(0.0485)
Trade Exposure Indicator				-0.0033	0.0177	-0.0050	0.0167
				(0.0090)	(0.0118)	(0.0088)	(0.0119)
Trade Index				-0.0173	-0.0775**	-0.0197	-0.0800**
				(0.0247)	(0.0369)	(0.0223)	(0.0360)
DI*Trade Index					0.2392**		0.2547**
					(0.1057)		(0.1201)
DO*Trade Index						0.0248	-0.0397
						(0.1539)	(0.1357)
Constant	-0.0136***	-0.0113**	0.0098	-0.0095**	0.0098	-0.0086*	0.0108
	(0.0035)	(0.0046)	(0.0169)	(0.0041)	(0.0169)	(0.0044)	(0.0161)

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 572 observations. Industry is by NAICS.

Table 7: Robustness to Including Debt-Equity Ratio Control

	1	2	3	4	5	6	7
Dirty Output Indicator		-0.0025				-0.0010	0.0000
		(0.0029)				(0.0026)	(0.0023)
DO Index		-0.0128***				-0.0136***	-0.0146***
		(0.0031)				(0.0037)	(0.0040)
Dirty Input Indicator			-0.0016		-0.0010		-0.0010
			(0.0045)		(0.0048)		(0.0047)
DI Index			-0.0219**		-0.0480*		-0.0496*
			(0.0108)		(0.0255)		(0.0274)
Trade Exposure Indicator				-0.0044	0.0061	-0.0045	0.0059
				(0.0039)	(0.0058)	(0.0039)	(0.0060)
Trade Index				0.0039	-0.0076	0.0052	-0.0097
				(0.0041)	(0.0123)	(0.0066)	(0.0122)
DI*Trade Index					0.0425		0.0513
					(0.0442)		(0.0515)
DO*Trade Index						-0.0300	-0.0106
						(0.0270)	(0.0319)
Debt-Equity Ratio	0.0012***	0.0009**	0.0008**	0.0010**	0.0008*	0.0008**	0.0006
	(0.0003)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Constant	-0.0037**	-0.0016	0.0011	-0.0026	0.0011	-0.0010	0.0025
	(0.0016)	(0.0019)	(0.0040)	(0.0022)	(0.0040)	(0.0021)	(0.0044)

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 572 observations. Industry is by NAICS.

Table 8: Robustness to no CAPM (Cumulative returns)

	1	2	3	4	5	6	7
Dirty Output Indicator		-0.0044				-0.0025	-0.0013
		(0.0031)				(0.0028)	(0.0025)
DO Index		-0.0084**				-0.0096***	-0.0108***
		(0.0034)				(0.0035)	(0.0038)
Dirty Input Indicator			-0.0011		-0.0005		-0.0008
			(0.0037)		(0.0039)		(0.0038)
DI Index			-0.0258**		-0.0501**		-0.0502*
			(0.0111)		(0.0240)		(0.0258)
Trade Exposure Indicator				-0.0032	0.0078	-0.0026	0.0080
				(0.0040)	(0.0056)	(0.0038)	(0.0056)
Trade Index				-0.0018	-0.0127	0.0000	-0.0139
				(0.0047)	(0.0118)	(0.0072)	(0.0122)
DI*Trade Index					0.0406		0.0468
					(0.0419)		(0.0486)
DO*Trade Index						-0.0310	-0.0080
						(0.0287)	(0.0326)
Constant	-0.0108***	-0.0084***	-0.0063*	-0.0093***	-0.0063*	-0.0079***	-0.0048
	(0.0015)	(0.0016)	(0.0033)	(0.0018)	(0.0033)	(0.0017)	(0.0036)

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 572 observations. Industry is by NAICS.

Table 9: Spillovers to the United States (data from S&P 500)

	1	2	3	4	5	6	7
Dirty Output Indicator		-0.0089				-0.0048	-0.0051
		(0.0073)				(0.0066)	(0.0066)
DO Index		0.0162 **				0.0140 *	0.0140 *
		(0.0067)				(0.0075)	(0.0081)
Dirty Input Indicator			-0.0042		-0.0017		-0.0030
			(0.0055)		(0.0069)		(0.0075)
DI Index			-0.0308 *		-0.0687		-0.0668
			(0.0165)		(0.0488)		(0.0495)
Trade Exposure Indicator				-0.0021	0.0112	0.0021	0.0149
				(0.0087)	(0.0101)	(0.0082)	(0.0101)
Trade Index				-0.0096	-0.0305	-0.0070	-0.0328 *
				(0.0131)	(0.0208)	(0.0101)	(0.0193)
DI*Trade Index					0.0903		0.1165
					(0.0865)		(0.0851)
DO*Trade Index						-0.1648 *	-0.1609
						(0.0905)	(0.0991)
Constant	-0.0063 **	-0.0044	0.0015	-0.0031	0.0015	-0.0039	0.0018
	(0.0029)	(0.0035)	(0.0034)	(0.0041)	(0.0034)	(0.0047)	(0.0034)

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 572 observations. Industry is by NAICS.

Table 10: Counterfactual Event Study for April 2004.

	1	2	3	4	5	6	7
Dirty Output Indicator		0.0009				-0.0027	-0.0023
		(0.0044)				(0.0035)	(0.0033)
DO Index		-0.0040				0.0005	-0.0001
		(0.0067)				(0.0045)	(0.0041)
Dirty Input Indicator			-0.0055**		-0.0069***		-0.0072***
			(0.0026)		(0.0025)		(0.0027)
DI Index			0.0052		-0.0159		-0.0148
			(0.0146)		(0.0302)		(0.0307)
Trade Exposure Indicator				0.0226***	0.0269***	0.0236***	0.0275***
				(0.0065)	(0.0092)	(0.0067)	(0.0094)
Trade Index				-0.0367***	-0.0354*	-0.0349***	-0.0354*
				(0.0109)	(0.0182)	(0.0121)	(0.0190)
DI*Trade Index					-0.0066		-0.0047
					(0.0476)		(0.0505)
DO*Trade Index						-0.0248	-0.0041
						(0.0301)	(0.0376)
Constant	-0.0027	-0.0028	0.0019	-0.0052***	0.0019	-0.0046***	0.0027
	(0.0018)	(0.0018)	(0.0014)	(0.0014)	(0.0014)	(0.0016)	(0.0019)

Notes: Significance is noted at the 10% (*), 5% (**) and 1% (***) levels. Standard errors are robust. There are 531 observations. Industry is by NAICS.