The Value Relevance of Greenhouse Gas Emissions under the European Union Carbon Emissions Trading Scheme

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Abstract

This study examines the valuation relevance of greenhouse gas emissions under the European Union Carbon Emission Trading Scheme (EU ETS). We posit that carbon emissions affect firm valuation only to the extent that a firm's emissions exceed its carbon allowances under a cap and trade system and the extent of its inability to pass on carbon related compliance costs to consumers and end users. We measure a firm's inability to pass on the future costs by its market power and its carbon performance relative to its industry peers. The results show that firms' carbon allowances are not associated with firm valuation but the allocation shortfalls are negatively associated. We also find that the negative association between firm values and carbon emission shortfalls is mitigated for firms with better carbon performance relative to their industry peers and for firms in less competitive industry sectors. These findings, which suggest that the valuation impact of carbon emissions is unlikely to be homogenous across firms or industrial sectors, have important implications for future research design and for the disclosure and recognition of a firm's greenhouse gas liabilities.

1. Introduction:

Concerns about climate change have prompted governments in some jurisdictions to implement policies and regulations aimed at curtaining industrial carbon emissions. One way that governments and regulatory bodies can regulate and control firm carbon emissions is through a cap and trade system, whereby an emissions limit (cap) is set for an entire industry. The cap amount, called carbon allowances or permits, can then be allocated to individual installations either freely or via auction. Once the initial allocation of the carbon permits is complete, the permits can then be traded on the market. In a cap and trade system, a firm must deliver carbon permits equal to its emissions, and it can buy or sell carbon permits that it needs or does not need.

Economists have argued that a cap and trade system is the most cost effective way to reach country level abatement targets (e.g., Goodstein, 2002).[1] Firms have the choice of making abatement investments to reduce emissions or purchasing emission permits on the open market. In equilibrium, given well-functioning markets for carbon permits, firms will invest in abatement up to the point where the marginal cost equals the permit price (Matisoff, 2010). Beyond that point, firms will opt to purchase permits. In this sense, a cost effective equilibrium is reached. Regardless of whether a firm invests to reduce emissions, or buys permits, the firm is absorbing a carbon cost that previously was an externality not considered by the firm in its decision making.

This increased cost as a result of complying with the cap-and-trade emission reduction system has also prompted accounting standard setters to call for increased disclosure and proper reporting of firms' carbon liabilities (e.g., Ertimur *et al.*, 2011; PriceWaterhouseCooper, 2007). Accounting standard setters appear to be concerned that increased carbon compliance costs represent future liabilities with a negative connotation for firm value. While Laine (2010) observes that firms are increasingly integrating sustainability disclosures into their overall disclosure package to

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[1] Goodstein (2002, p. 314) discusses the difference between a cap and trade system versus a carbon tax system, pointing out that a cap and trade system is much less costly than pollution taxes for affected firms when permits are initiated through a free allowance allocation system and in addition, that a carbon tax system will create additional costs for monitoring and enforcements on the part of the government.

stakeholders, Bebbington and Larrinaga-Gonzalez (2008) call for non-financial reporting which improves disclosures to stakeholders about the risks that arise from global climate change. Further, Kolke *et al.* (2008) cite the need for stricter carbon disclosure to ensure comparability and the provision of relevant data needed by investors and other firm stakeholders to assess carbon performance, risk and opportunities facing the firm.

There is a consensus in the economics literature that compliance with any form of environmental regulation will likely increase a firm's costs. What is unclear is the extent to which such compliance-related costs will actually reduce the firm's future profits and hence diminish returns to shareholders because firms differ in their ability to pass on these costs to consumers and end-users. Economic theory dictates that the distributional effects of environmental regulations such as a cap-and-trade system depend on how such regulations affect the substitution of various production inputs in a general equilibrium (Fullerton and Heutel, 2007). For example, to the extent that no economically viable substitute for fossil fuel exists at the present time, society as a whole should bear the costs of carbon emissions. The essence of a cap-and-trade system is that society collectively chooses an acceptable level of carbon emissions (the cap amount) and allocates this level to various production facilities through allowances either by free allocation or auction. If the carbon allowance allocation system functions properly, in theory the allocated allowances to each firm should reflect the carbon efficiency that is acceptable to society. This discussion has important implications for the empirical research design in this study. It implies that we should not expect a negative valuation impact for the portion of a firm's total emissions that are offset by its carbon allowances. Thus, only firms with carbon emissions that exceed their carbon allowances should have a compliance liability and thereby suffer from negative valuation as a result of their excess carbon emissions. In addition, firms should be able to pass on some of their carbon compliance costs to consumers depending on the ability to do so in a given competitive environment.

This study examines the extent to which carbon emissions in a cap-and-trade system affect firm value and the economic factors that investors consider when assessing a firm's carbon liability in different industry contexts and competition environments. Specifically, we address the following two related research questions within the context of the European Union (EU) Emissions Trading Scheme (ETS): (1) Do investors consider the level of carbon allowances when assessing a firm's carbon liability? and (2) Do investors consider differences in firms' capabilities to pass on carbon costs to consumers and end users? In this sense, we are responding in part to the call by Carmona in a recent *European Accounting Review* editorial for research examining the actual implementation of cap and trade systems (Carmona, 2009).

The extant literature has documented the existence of latent carbon liabilities within jurisdictions wherein no such 'cap and trade' regime exists. For example, Griffin *et al.* (2011) and Matsumura *et al.* (2011) focus on the U.S. setting while Chapple *et al.* (2011) focuses on the Australian setting. Each of these studies uses total emissions as their proxy for the valuation impact of climate change regulation. However, industry research (e.g., IRRC Institute and Trucost, 2009; Deutsche Bank, 2009) argues that the valuation impact of carbon emissions depends not only on a firm's total emissions but additionally on policy outcomes, notably the allocation of free allowances that it receives and its ability to pass on its carbon-related costs.

This study extends the literature in four important ways. First, by conducting our study within the context of the EU ETS, we are able to directly evaluate the valuation impact associated with the allocation of free carbon allowances. A significant issue in the proposed financial reporting framework issued in December 2004 by the IASB (IFRIC 3) is that it advocates recognizing allowances as intangible assets based on the fair value regardless of how these allowances are acquired.[2] The argument in support of this position is that purchased allowances are identical to allocated allowances and therefore they should be treated the same way to facilitate comparability. Although the argument that allocated allowances represent "rights" and fit the definition of the intangible assets seems compelling, we will shed light on this argument by examining their valuation relevance in the capital market setting. In contrast, a consideration of policy outcomes

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[2] The IASB withdrew IFRIC #3 in 2005. One reason for the withdrawal is that its application created significant income volatility (Ertimur *et al.*, 2011).

such as the allocation of free allowances is not possible in the previously cited studies which have been conducted within jurisdictions without enacted carbon emissions legislation.

Second, economic theory indicates that the valuation impact of carbon emissions should be related to a firm's cost pass on ability. Grainger and Kolstad (2010) argue that the costs of carbon regulations are ultimately borne by consumers, shareholders, and workers through changes in consumer prices, stock returns, wages and other returns to factors in production. Fullerton and Heutel (2007) show in an equilibrium model, that environmental regulation in the form of a carbon tax can actually increase the return to capital if consumers are less able to substitute among goods. Grainger and Kolstad provides empirical evidence that the price of carbon induced by a cap-and-trade program or carbon tax in the context of the U.S. has a large impact on consumers, disproportionally so for the low income householders. Firms likely differ in their ability to pass on the increased future carbon compliance costs to consumers because of the structure of their industry and/or their carbon performance relative to sector peers. Thus, a natural extension to the studies cited above is to examine whether a firm's cost pass on ability will mitigate the valuation impact of its carbon emissions.

Third, by adopting the EU ETS as our experimental setting, we are examining the valuation of a carbon liability in a setting where the reporting of carbon emissions is mandatory and where it is known with certainty that carbon emissions will be priced. In contrast, prior studies have examined the valuation of carbon emissions based on samples of firms that voluntarily self-report their carbon emissions data through outlets such as the Carbon Disclosure Project (CDP). This gives rise to the possibility of substantial self-selection bias on coefficient estimates (Maddala, 1991; Lennox *et al.*, 2012). Fourth and finally, carbon liabilities arise from a legal setting where effective carbon emissions monitoring and enforcements exist. Thus, the stringency and intensity of judicial regimes should impact investors' assessment of carbon liabilities. We examine the valuation impact of carbon emissions both in and outside the EU ETS zones for our sample firms. This allows us to both compare the impact of differences in carbon emissions enforcement jurisdictions on the assessed carbon liability and to reconcile findings in our study with those in the existing studies.

To conduct our study, we employ a modified version of the Ohlson (1995) valuation model to explore the valuation relevance of the carbon emissions data. In the context of the Ohlson model, carbon emissions represents “other information” which captures the firm’s exposure to compliance costs associated with current or possible future carbon regulatory regimes. Using a sample of 843 firm-year observations from the EU ETS over the period 2006-2009, we find, as predicted, that the impact of carbon emissions on firm value in the EU ETS is not uniform. Specifically, we find that a firm’s latent carbon liability: (1) relates to the portion of emissions that exceed free allowances within the EU ETS, (2) is mitigated by its ability to pass on the future compliance costs to consumers, and (3) differs for carbon emissions within the EU ETS versus those in non-EU ETS jurisdictions. Our findings are robust to different model specifications and proxy measures.

The findings in this study have a number of important implications. First, our findings indicate that the valuation impact of carbon emissions is not homogenous across firms and industries. Investors appear to assess a firm’s latent carbon liability in the context of its allocated allowance, its competitive position and relative carbon efficiency, and the relevant carbon enforcement in different legal jurisdictions. Future research in this area must therefore give explicit consideration to these factors when assessing a firm’s carbon-related liabilities.

Second, our findings may assist securities regulators and accounting standard setters in their future policy delivery with respect to the disclosure of firms’ future carbon liability. Our results indicate that, at a minimum, investors need the following information in order to estimate latent carbon liabilities: (1) current carbon emissions at the corporate entity level, segregated by regions under different regulatory regimes; (2) the firm’s carbon efficiency relative to its sector peers for each sector the company operates in; and (3) other information indicating the firm’s ability to pass on increased carbon costs to consumers. The accounting profession and standard setters are currently debating on a framework for disclosure and recognition of carbon related liability

(Bebbington and Larrinaga-Gonzalez, 2008; Veith *et al.,* 2009, Ertimur *et al.*, 2011). In particular, existing accounting practices can be broadly classified into two groups: the “net approach” and the “gross approach.”[3] Under the “net approach”, allocated allowances have zero costs and firms will accrue carbon liabilities only when the actual emissions exceed the allocated allowances. The “net approach” is more consistent with the economic theory in that carbon liabilities exist only when actual emissions exceed the expectations. The shortcoming of this approach is that it allows different accounting treatments for otherwise identical carbon allowances depending on how they are acquired, thus failing the requirement for comparability. Under the “gross approach,” firms record allowances as carbon assets based on their fair value and accrue carbon liabilities as actual emissions occur. This approach treats carbon allowances consistently but it creates a timing mismatch between carbon assets and carbon liabilities because the receipt of carbon allowances and the actual carbon emissions occur at a different time, casting doubts on its relevance and faithful representation. Our findings that carbon allowances are not valuation relevant and carbon allocation shortfalls confer liabilities are more consistent with the “net approach.” These findings indicate that the “net approach” meets the criteria of both relevance and faithful representation with respect to reporting a firm’s carbon liability. Our findings do not support the “gross approach” as being relevant and a faithful representation of the economic reality of the reporting entity.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature and develops our hypotheses. We discuss our empirical research design and methodology to test the hypotheses in Section 3. Section 4 describes the data sources and summary statistics. We present and discuss the empirical results in Section 5. Section 6 concludes.

2. Literature review and hypothesis development

Academic research examining the valuation implications of a firm’s environmental performance has followed several approaches, with some analyzing the financial performance and

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[3] See Ertimur *et al.* (2011), PriceWaterhouseCooper (2007) and Veith *et al.* (2009) for a summary of the existing accounting practice with respect to carbon liability reporting.

cost of capital and others focusing directly on the market value itself. Studies that examine the relationship between environmental and financial performance include Jaggi and Freedman (1992), Hart and Ahuja (1996), and Clarkson *et al.*, (2011). For example, using Toxic Release Inventory (TRI) data reported to the U.S. EPA to measure environmental performance, Clarkson *et al.* show that firms with marked improvement in environmental performance experience significant improvement in financial performance in subsequent periods, a finding consistent with the argument that improved environmental performance leads to future competitive advantages. Alternatively, others have focused on the relationship between environmental performance and the cost of equity capital. These studies include Sharfman and Fernando (2007) and Connors and Silva-Gao (2009), both of which find using TRI data, that firms exhibiting better environmental performance benefit from a lower cost of capital.

For the purposes of this study, the literature directly investigating the effect of environmental performance on market value is the most relevant. These studies, which include Cormier *et al.* (1993), Hughes (2000), and Clarkson *et al.* (2004), are commonly conducted using valuation models typically based on Ohlson (1995), although a number of studies have employed event study methodology (e.g., Klassen and McLaughlin, 1996; Hamilton, 1995).

Studies that rely on the Ohlson (1995) model have, in general, found a negative association between environmental performance and firm value. For example, Cormier *et al.* (1993) investigate the relation between market valuation and social performance, measured by a firm’s pollution record relative to environmental regulations, finding that pollution performance is interpreted by the market as providing information about environmental liabilities. Hughes (2000) uses sulphur dioxide emissions to assess the value-relevance of future environmental liabilities faced by electric utilities as a result of Phase One of the 1990 Clean Air Act Amendments. He concludes that, on average, exposure to unbooked future environmental liabilities decreased the mean 1990 share price of the relevant utilities by 16%. Similar conclusions follow from Clarkson *et al.* (2004) based on a sample of U.S. pulp and paper firms. They find that investors use TRI data to assess unbooked environmental liabilities, which they interpret to represent future abatement spending obligations of high-polluting firms, equal to approximately 16.6% of market capitalisation. Support for figures of this magnitude also follow from Barth and McNichols (1994) who estimate investors' assessment of firm's unrecognised environmental liabilities (proxied by number of Superfund sites) to be 28.6% of equity.

Turning to the studies that use the event study framework, two stand out as being particularly relevant. Klassen and McLaughlin (1996) find significant positive returns for strong environmental management as indicated by positive news related to winning environmental performance awards and significant negative returns for weak environmental management as indicated by negative news environmental crises. Hamilton (1995) examined the market reaction to the first release of TRI data in the U.S. He found that firms experienced an average loss of $4.1 million in market value, suggesting that investors increased the present value of estimated pollution costs by this amount, on average. Hamilton's results were stronger for firms which enjoyed media coverage of their releases (-$6.2 million) and firms with Superfund sites (-$5.9 million).

Finally, several studies are of more direct relevance to our focus on the valuation implications of carbon emissions. To begin, Johnson *et al.* (2008) examine the value relevance of sulfur dioxide (SO_2) emission allowances held by U.S. electric utilities. While explicitly recognizing that SO_2 is not a greenhouse gas (GHG), they argue that their examination has the potential to inform the GHG debate because the SO_2 allowances have been subject to a cap and trade market since 1995. They find that the SO_2 emission allowances are valued by the market, with the value comprised of two components, an asset value and a real option value.

Three recent studies directly examine the valuation of carbon emissions data, each documenting a valuation decrement related to the firm's carbon emissions profile. First, Chapple *et al.* (2011) examine the valuation relevance of the proposed Australian carbon emissions trading scheme using a sample of 58 firms in 2007. Using both event study and Ohlson-type valuation model methodology, they find that the market assesses the most carbon intensive firms a decrement of between 7% and 10% of market capitalization relative to other sample firms.

Second, Griffin *et al.* (2011) focus on U.S. and Canadian firms drawn from the S&P 500 and the TSE 200, respectively. They obtain their carbon emissions data either directly from CDP disclosures or by estimating it for non-disclosers based on the emissions data provided by firms that do disclose. Also using both event study and valuation model methodology, their results lead them to conclude that their analysis "generates two key findings: (1) that greenhouse gas emissions levels associate negatively with stock price, and (2) that the negative relation between emissions and price is more pronounced for carbon-intensive companies."

Last, Matsumura *et al.* (2011) examine both the decision to voluntarily disclose carbon emissions data and the valuation relevance of a firm's carbon emissions. They find that firms which are more environmentally proactive are more likely to disclose their carbon emissions levels. Moreover, they find a negative association between carbon emissions and firm value where, based on the estimated relationship, they suggest that their results imply an assessed penalty of $202 per ton of emissions. Finally, noting that this assessed value per ton far exceeds the spot price of carbon, they suggest that the penalty also reflects the present value of the firm's future carbon emissions, as well as other indirect costs associated with carbon emissions such as regulatory intervention, litigation and remediation expenses, and potential reputational implications.

A common feature in the research design of the final three studies above is the use of total carbon emissions as a proxy for the firm's future carbon liability in the valuation model. Two basic assumptions underlie this design. The first is that a valuation benchmark for carbon emissions exists, whether formal or informal, in order that they can be priced. The second is that investors will assess a firm's carbon liability uniformly based on its actual carbon emissions. However, this second assumption, which implies that firms that generate carbon emissions must fully absorb or internalize the carbon compliance liability, likely represents an incomplete view for two reasons. First, any allocation of free allowances can be used to offset a firm's carbon liability relating to its total emissions. Thus, only firms with carbon emissions in excess of their carbon allowances will have a direct compliance liability. In this sense, it is likely that these two components of a firm's total carbon emissions, those covered by free allowances and those in excess of the allowances, will be viewed by the market as having different carbon liability implications.

Second, it is likely that firms will have some capacity to pass their carbon emissions-related costs on to consumers. Further, even if carbon compliance costs raise production costs for all firms, firms will differ in their ability to pass on these costs to end consumers and so, the net impact of carbon compliance costs on future profits will differ across firms and industries. For example, using industry level data in five high polluting industries in the U.K., Smale *et al.* (2006) show that although carbon prices increased the marginal production costs uniformly for the five industries (cement, newsprint, petroleum, steel, and aluminium), four of the five industries actually experienced an increase of different magnitudes in EBITA. Sijim *et al.* (2006) explore the impact of the EU ETS on the power sector in Germany and the Netherlands, finding that the power companies can pass through between 60% and 100% of their carbon compliance costs to consumers. These studies suggest that to fully assess the valuation impact of carbon compliance costs, it is important to consider a firm's ability to pass on the increased carbon costs to consumers.

This study extends the existing literature on the valuation implications of carbon emissions by giving explicit consideration to both the existence of free allowances under the EU cap and trade system, and the firm's ability to pass on carbon compliance costs to consumers. To re-iterate, we first argue that the portion of a firm's total emissions covered by carbon allowances will have a different valuation impact from the portion which is not covered (i.e., the "shortfall"). Second, to the extent that consumers cannot find economically viable substitutes for fossil fuel, we argue that the negative valuation impact of carbon emissions will be mitigated by the firm's ability to pass the cost on to the ultimate customer (Grainger and Kolstad, 2010; Fullerton and Heutel, 2007). We formalize these arguments in the following two hypotheses;

H_1: The market values the portion of total emissions covered by free allowances differently than the shortfall not covered by free allowances.

H_2: A firm's carbon cost pass on ability will mitigate the negative valuation impact of carbon emissions.

A firm's carbon liability originates largely from the need to comply with carbon-related regulations. It is natural to expect that variation in the stringency of the regulation and carbon enforcement in different jurisdictions will impact the market valuation of a firm's carbon liability. Our final hypothesis explores the valuation impact of a firm's global carbon emissions within the context of the EU ETS. One unique feature of the EU ETS is that it "legalizes" the carbon emission liability for firms operating in the EU zone. In contrast, significant uncertainty exists with respect to the form, if any, that future carbon enforcement mechanisms may take in many other economies. The EU ETS has established a sophisticated system to monitor actual emissions at the plant level and then enforce compliance with the permitted emissions level. The valuation impact of a firm's liability can be assessed based on its emissions and its shortfall given the free allowances that it has been allocated. In contrast, much of the rest of the world is still debating on the reality of climate change and many governments, including the U.S. and Canada, remain uncommitted with respect to specific regulations on carbon emissions. Since carbon emissions is a global issue, the lack of will and consistency in global regulations and enforcements creates uncertainty on how to assess the future compliance costs for firms operating in regions outside the EU ETS. The lack of commitment by the non EU ETS countries will affect investors' perceptions about the likelihood, scope and stringency of future carbon emissions enforcement in these countries. Investors may not, therefore, apply the same valuation multiple for carbon emissions outside of the EU ETS countries. Thus, we hypothesize the valuation impact of carbon emissions in the EU ETS differs from the carbon emissions from non-EU ETS zone as follows:

H_3: The valuation impact of EU ETS carbon emissions differs from that of carbon emissions from non-EU ETS zones.

3. Research Methodology

This section discusses our empirical research design and methodology to test the three hypotheses developed in the previous section. To do so, we begin by observing:

$$\begin{aligned} EmitTot &= (EmitTot - PerAlloc) + PerAlloc \\ &= AllocShort + PerAlloc \qquad (1) \end{aligned}$$

where

$EmitTot$ = the firm's total EU carbon emissions;

$PerAlloc$ = the firm's carbon allowance under the EU ETS, a proxy that captures the "acceptable" carbon emissions; and

$AllocShort$ = the firm's permit allocation shortfall.

This disaggregation forms the basis for our econometric models designed to test each of our three hypotheses. These models are described in turn in dedicated sections below.

3.1 Tests of H_1

To test H_1, we implement a modified Ohlson (1995) valuation model. The decomposition presented in equation (1) above leads us to the following specification:

$$V = \alpha_0 + \alpha_1 BV + \alpha_2 AE + \alpha_3 AllocShort + \alpha_4 PerAlloc + \varepsilon \qquad (2)$$

where

V = market value of common equity, measured at the end of April following year end;[4]

BV = book value of common equity;

AE = abnormal earnings to common defined as earnings to common equity less an assumed cost of capital based on the CAPM times beginning-of-period book value of common equity;[5] and

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[4] We measure stock price as the end of April to coincide with the date that carbon emissions are disclosed (see Section 4.1). Sensitivity analysis using year-end price and price 3 months after fiscal year-end reveal the results to be robust.

[5] The cost of equity capital is based on the CAPM with β estimated using 60 months of historical return data, R_F equal to 5.0 percent, and the market price of risk ($[E(R_M) - R_F]$) equal to 6.0 percent. Sensitivity analysis indicates that results are not sensitive to a reasonable range of figures for either the risk-free rate or the market price of risk.

remaining variables are as defined above. For this and all subsequent models, the regressions are run with corrections for clustering by firm, industry, and year (as appropriate) (Petersen, 2009), and reported *p*-values are two-tailed.

Note, for the period of our study, recent historical emissions provided the basis for the allocation of free allowances to individual installations (Ellerman and Joskow, 2008, p. 36).[6] Consistent with the existence of latent carbon liabilities, we expect a negative coefficient on *AllocShort* ($\alpha_3 < 0$). The predicted coefficient on *PerAlloc* may also differ from zero. As explained by Matisoff (2010), the 2013-2020 Phase 3 period of the EU ETS will incorporate fully auctioned allowances, for electricity generators, and 20 percent auctioned allowances for other industrial firms in 2013, increasing to 70 percent auctioned allowances in 2020. Thus, emissions covered by free allowances in Phases 1 and 2 may not be fully covered in Phase 3, leaving it an empirical issue as to whether the coefficient on *PerAlloc* is zero. Irrespective, as predicted by H_1, we expect the valuation coefficient on *AllocShort* to be more negative than that on *PerAlloc* (i.e., $\alpha_3 < \alpha_4$).

3.2 Tests of H_2

To test H_2, we measure pass on ability from two perspectives, one at the industry level and one at the firm level. In conjunction, we also consider the interplay of the two perspectives. Beginning at the industry level, we argue that firms with more market power (concentration) and facing less competition will be able to pass on the increased carbon compliance costs to consumers more completely than firms with less market power (Sijim *et al.*, 2006). We use the Herfindahl-Hirschman (*HH*) index as a proxy for market power and interact this proxy with the two carbon emission variables in equation (2) above. Thus, we initially test H_2 using the following equation:

$$V = \alpha_0 + \alpha_1 BV + \alpha_2 AE + \alpha_3 HH + \alpha_4 AllocShort + \alpha_5 PerAlloc \\ + \alpha_6 AllocShort*HH + \alpha_7 PerAlloc*HH + \varepsilon \qquad (3)$$

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[6] As a result, allowances partially reward inefficiency and thereby sector relative efficiency interpretations do not apply to either *PerAlloc* or *AllocShort*.

Since higher values of *HH* correspond to less competition and thereby greater market power, we expect α_6 (and potentially α_7, dependent on how *PerAlloc* is valued) to be positive, consistent with a reduced valuation impact of carbon compliance costs in more concentrated industries.

Alternatively, from the firm-level perspective, we explore whether a firm's carbon efficiency relative to sector peers will affect its carbon cost pass on ability. To quote IRRC Institute and Trucost (2009), "companies that are more carbon efficient than sector peers stand to gain competitive advantage. Carbon pricing could create opportunities for low-emission companies in carbon-intensive sectors. High emitters which find it difficult to fully pass these liabilities on could see profits fall." Put another way, high emitters in their sectors face the cost of purchased emission permits which they cannot pass on or, alternatively, face higher carbon spending obligations to reduce emissions to a level achieved by their more efficient sector rivals. Either way, future profits will fall more, per ton of emissions, for high emitters.[7] Following the argument in IRRC Institute and Trucost (2009), we consider the firm's relative industry-year carbon intensity, where carbon intensity is defined as carbon emissions deflated by sales. To measure carbon intensity in a given year, we determine the percentile rank of the firm's emissions scaled by sales in each of the industry sectors it operates in.[8] We then determine the equal-weighted average percentile rank across its sectors and denote this average as *Rank*, with larger values reflecting superior performance (i.e. corresponding to lower carbon intensity relative to its industry peers). Accordingly, our next empirical specification is as follows:

$$\begin{aligned} V = {} & \alpha_0 + \alpha_1 \, BV + \alpha_2 \, AE + \alpha_3 \, Rank + \alpha_4 \, AllocShort + \alpha_5 \, PerAlloc \\ & + \alpha_6 \, AllocShort{*}Rank + \alpha_7 \, PerAlloc{*}Rank + \varepsilon \end{aligned} \tag{4}$$

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[7] To illustrate, consider two sector rivals in an oligopolistic industry where the low emitter has 1 ton of direct emissions per €1,000 of sales not covered by free allowances while the high emitter has 10 tons per €1,000 of sales not covered by free allowances. Assume further, given the elasticity of demand, both firms can pass the costs of purchased permits for just 1 ton of emissions on to customers. In this setting, the high emitter has no pass on ability for 9 of its 10 tons, since price is set by the low cost producer (the low emitter).

[8] We obtain the actual emissions from the European Emission trading registry for each of the operators owned by the parent entities in our sample. We use the industry classification of the installations owned by the operators provided by the EU ETS registry in accordance Annex 1 of the Directive I. This industry classification is the one in which the operators within each industry are most likely to be homogenous with respect to the production process giving rise to emissions and thus arguably yields the most precise relative emission performance ranking.

Based on the above discussion, we expect α_6 (and potentially α_7) to be positive, reflective of argument presented above that firms superior industry-year carbon intensity performance (higher values of *Rank*) will exhibit lower carbon liabilities, through either a higher cost pass on ability and/or reduced future spending obligations.

Relatedly, we consider changes in the firm's relative carbon intensity profile over the immediate past, arguing that firms showing greater improvement in their carbon intensity rank will suffer a smaller valuation penalty since the market will infer greater future emission reductions for such firms. To implement this conjecture empirically, we determine the firm's change in industry-year percentile rank (*Rank*) over the prior two years, and then use this difference as our measure of the firm's recent improvement. Denoting this change as *ΔRank*, our valuation model becomes

$$V = \alpha_0 + \alpha_1 BV + \alpha_2 AE + \alpha_3 \Delta Rank + \alpha_4 AllocShort + \alpha_5 PerAlloc + \alpha_6 AllocShort * \Delta Rank + \alpha_7 PerAlloc * \Delta Rank + \varepsilon \quad (5)$$

Based on the above discussion, we again expect α_6 (and potentially α_7) to be positive.

In conjunction, we also conduct the following analyses which incorporate both industry and firm level pass on measures to ensure that our results are robust to different specifications,

$$V = \alpha_0 + \alpha_1 BV + \alpha_2 AE + \alpha_3 Rank + \alpha_4 HH + \alpha_5 AllocShort + \alpha_6 PerAlloc + \alpha_7 AllocShort*Rank + \alpha_8 PerAlloc*Rank + \alpha_9 AllocShort*Rank * HH + \alpha_{10} PerAlloc*Rank * HH + \varepsilon \quad (6)$$

$$V = \alpha_0 + \alpha_1 BV + \alpha_2 AE + \alpha_3 \Delta Rank + \alpha_4 HH + \alpha_5 AllocShort + \alpha_6 PerAlloc + \alpha_7 AllocShort * \Delta Rank + \alpha_8 PerAlloc*\Delta Rank + \alpha_9 AllocShort * \Delta Rank * HH + \alpha_{10} PerAlloc*\Delta Rank * HH + \varepsilon \quad (7)$$

3.3 Tests of H_3

Finally, to test H_3 regarding the valuation difference between EU and non-EU (global) emissions, we begin by noting the following further decomposition:

$$\begin{aligned} \text{Global GHG emissions (CDP emissions)} &= \text{EU emissions} + \text{non-EU emissions} \\ &= AllocShort + PerAlloc + NonEUemission \quad (8) \end{aligned}$$

Based on this decomposition, we modify equation (2) by inserting these terms which comprise global GHG emissions as reported to the CDP. This leads to our final econometric model:

$$V = \alpha_0 + \alpha_1\ BV + \alpha_2\ AE + \alpha_3\ AllocShort + \alpha_4\ PerAlloc + \alpha_5\ NonEUemission + \varepsilon \qquad (9)$$

We expect *NonEUemission* to have a smaller impact on firm value than *AllocShort* because there are no clear legal obligations for carbon emissions outside of the EU ETS zone, and hence its coefficient be less negative (i.e., $\alpha_4 < \alpha_5$).

In conjunction, we also conduct analyses which alternatively incorporate *Rank* and *ΔRank* to investigate whether firm-level cost pass through ability has the same mitigation effects on the negative valuation implications of the EU and non-EU components of the firm's global GHG emissions. Here, following the forms of equations (4) and (5) above, the regression models are:

$$\begin{aligned} V = {} & \alpha_0 + \alpha_1\ BV + \alpha_2\ AE + \alpha_3\ Rank + \alpha_4\ AllocShort + \alpha_5\ PerAlloc + \alpha_6\ NonEUemission \\ & + \alpha_6\ AllocShort *Rank + \alpha_7\ PerAlloc *Rank + \alpha_8\ NonEUemission*Rank + \varepsilon \qquad (10) \end{aligned}$$

$$\begin{aligned} V = {} & \alpha_0 + \alpha_1\ BV + \alpha_2\ AE + \alpha_3\ \Delta Rank + \alpha_4\ AllocShort + \alpha_5\ PerAlloc + \alpha_6\ NonEUemission \\ & + \alpha_6\ AllocShort *\Delta Rank + \alpha_7\ PerAlloc *\Delta Rank + \alpha_8\ NonEUemission*\Delta Rank + \varepsilon \qquad (11) \end{aligned}$$

As previously discussed, we conduct these final analyses based on the subsample of firms for which both CDP and EU GHG emissions data are available.

4. Data

We test H_1 and H_2 using firms that are covered in the EU ETS from 2006 to 2009. We then test H_3 using the subset of our EU ETS sample firms that also disclose their global GHG emissions to the CDP in the same period. We discuss each of the two sample sets in detail below.

4.1 The EU Sample

The EU sample consists of all firms for which carbon emissions and permit allocation data could be obtained over the period 2006 to 2009. Annual verified emissions and allocations for each participating installation in the EU ETS are recorded by the European Commission in the *Community Independent Transaction Log* (CITL). These data are then made publically available in April of the following year.

Our sample selection process began by identifying all installations from the CITL registered as participating in the EU ETS across the period 2005 to 2010. From the CITL, we then obtained a raw sample of approximately 10,000 installations. In order to identify if the installation is listed or it is owned by an immediate or ultimate parent entity that is listed, we used the BVD Amadeus Database. This database is a comprehensive database of all European entities that records the immediate and ultimate controlling entity of all entities operating in Europe and whether the entity is listed. Using this database and a combination of programming and follow-up hand-matching, we matched all installations to their respective controlling entities. The final sample comprised approximately 200 listed companies that controlled installations registered as participating in the EU ETS. For each listed entity for each year, we summed the emissions and allowances across all the individual installations under their control to arrive at the aggregated emissions and allowances of each listed entity.

Table 1 presents frequency distributions for the final sample of 843 firm-year observations by country, year, and industry. As revealed in Panel A, the number of observations was relatively constant across the 4-year study period, with only a modest increase from 197 observations in 2006 to 221 observations in 2009. In contrast, it also reveals that there was considerable disparity across the 21 countries represented in the sample. U.K. companies consistently represented the largest sample, ranging from 42 in 2006 to 51 in both 2008 and 2009, followed by Spain with 29 companies in each of the four years of the study period. In contrast, a number of countries exhibited three or fewer observations across all years. These countries include Ireland and Latvia, each with two observations in all years, Luxembourg and Romania with no observations in 2006 and 1 in each of the remaining three years, and the Netherlands and Slovenia for which the number of observations had increased to three in the later years of the study period.

Alternatively, Panel B of Table 1 presents a frequency distribution of the number of firm-year observations by industry sector. As revealed, the industry sectors with the greater representation are ‘1000 – Basic Metals’ with 192 firm-year observations, ‘2000 – Industrials’ with 223 firm-year observations, and ‘7000 – Utilities’ with 152 firm-year observations. In contrast, the financial and technology sectors, Sectors 8000 and 9000, only provided 4 and 8 firm-year observations, respectively. Additionally, the Oil & Gas sector (Sector 1) provided 78 firm-year observations while the consumer goods sector (Sector 3000) provided 136 firm-year observations. Thus, overall the sample draws good representation across the important sectors within the economy. Further and importantly, the sample draws good representation from sectors that are significantly affected by the carbon emissions trading scheme such as Oil & Gas, Basic Metals, and Utilities, as well as sectors likely much less affected such as Financials and Technology.[9]

Table 2 presents descriptive statistics for the pooled sample of 843 firm-year observations across both firm characteristics and the carbon emissions aspects of their performance. For the firm characteristics, figures have been converted from the domestic reporting currency to Euros (€) where necessary to provide a common basis for the pooling of the observations. As revealed in Panel A, there is reasonable cross-sectional variation in all firm characteristic measures. For market capitalization (V), its mean (median) value is €7.225 billion (€1.163 billion), with 1st and 99th percentile values of €10 million and €105.03 billion. For book value (BV) and earnings (E), the mean (median) values are €3.16 billion (€0.49 billion) and €57 million (€2.4 million), respectively, with 1st to 99th percentile ranges for two measures of €10 million to €43.17 billion (BV) and €-710 million to €9.22 billion (E). The firms also exhibit a reasonable degree of leverage, with LEV measured as debt to total assets having a mean (median) value of 0.61 (0.63.

Panel A also presents statistics relating to the composition of the sample firms’ assets. Here, $CAPINT$ is the proportion that net property, plant, and equipment represents of the firm’s total assets while $CAPEX$ is measured as current period capital expenditures divided by sales. Both the mean and median values of $CAPINT$ are 0.40, with 1st to 99th percentile range from 0.01 to 0.83. Alternatively, the mean (median) value of $CAPEX$ is 0.10 (0.06), with 1st to 99th percentile range

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[9] While the Financials and Technology sectors are unregulated under the EU ETS, companies from these sectors appear in the sample because they represent publicly listed parent companies with operations within regulated sectors. As noted above, the final sample comprises listed companies that controlled installations registered as participating in the EU ETS.

from 0.01 to 0.56. Thus, the sample firms appear to have a reasonable level of investment in capital assets, with property, plant, and equipment representing approximately 40% of a firm’s assets, on average, and also to spend a reasonable amount on capital assets, approximately 10% of their gross proceeds, on average.

Turning to the sample firms’ carbon emissions profile, descriptive statistics for total carbon emissions, carbon permit allocations, and permit allocation shortfall are presented in Panel B. All figures are presented in millions of tons. The permit allocation shortfall figure is measured as the different between a firm’s total emissions and its permit allocation, and represents the number of permits that the firm must acquire. Note, here a positive figure represents a shortfall, indicating that the firm is in a deficit position relative to its permit requirements. As revealed, the mean (median) total carbon emissions figure is 5.25 (0.15) million tons, with a 1st to 99th percentile range from 0.00 to 78.55 million tons. Further, the mean (median) permit allocation figure is 2.21 (0.11) million tons. On net then, as revealed by the ‘allocation shortfall’ mean figure of 3.04 million tons, firms on average experience a short fall of slightly in excess of 3 million permits which they must acquire through other means. The 1st to 99th percentile range for the ‘allocation shortfall’ figure is from -0.04 million tons (indicating a firm with excess permits) to 51.14 million tons (indicating a firm that is required to acquire 51.14 million permits). Based on the median ‘allocation shortfall’ figure of 0.03 million tons, the majority of firms are in a deficit position in terms of the carbon emissions permits. Here, untabulated figures reveal that 72.8% of the sample firms are in a deficit position and only 27.2% in a permit surplus situation. Consistent with this, while on average permits amount to 102.2% of a firm’s carbon emissions, the median proportion is only 0.598.

4.2 The CDP Subsample

To test our final hypothesis, we require measures of both the firm’s EU carbon emissions and its broader emissions in non-EU jurisdictions. To obtain the broader emissions data, we appeal to the CDP database. Respondents to the CDP survey report their total global emissions.

Within our sample of 843 EU firm-year observations, observations relating to 189 firm-years also have global emissions data available through the CDP. This subsample forms the basis for our test of the final hypothesis. As revealed in Panel A of Table 3, this subsample is larger, slightly more profitable, and more highly levered than the full sample. The mean values of *V* and *BV* are both significantly higher for the subsample at the 1% level, as is the mean value of *LEV*. While the subsample also higher mean and median profitability measures, the differences are not significant. Conversely, the subsample has lower mean values of *CAPINT* and *CAPEXP*, with the former difference significant at the 1% level and the latter significant at the 5% level.

Turning to the carbon emissions descriptive statistics, Panel B of Table 3 reveals that the subsample has both significantly higher total carbon emissions and permit allocations than the full sample, as well as a greater shortfall. The difference in mean total carbon emissions and allocation shortfall are statistically significant at the 5% level, while the difference in the mean permit allocation measure is significant at the 10% level.

Thus, overall, the subsample of firms that also voluntarily report to the CDP appear larger, slightly more profitable, more highly levered, but less capital intensive than the broader set of sample firms covered under the EU ETS. Further, they have greater carbon emissions in total and while they have more permit allocations, the net allocation shortfall is greater.

5. Empirical Results

5.1 Base Valuation Model Results

Table 4 presents results for variants of the base valuation regression model designed to examine the valuation impact of a firm's carbon emissions. In Panel A, we present results for a model which includes a measure of the firm's total carbon emissions (*EmitTot*) representing its gross exposure. In Panel B, we disaggregate total emissions following equation (1) into the portion covered by permit allocations (*PerAlloc*) and the consequent allocation shortfall (*AllocShort*). This disaggregated model is the one portrayed in equation (2). For each set of analyses, we present results for both the pooled data set of 843 firm-year observations with EU data and results by year.

Across all models in both panels, the coefficients on *BV* and *AE* are positive and highly significant. Further, their magnitudes are consistent with expectations, with the coefficients on *BV* slightly exceeding 1 and the coefficients on *AE* indicating an 'abnormal earnings multiplier' typically between 5 and 9. Finally, the adjusted R^2s are all slightly in excess of 0.8, consistent with the norm for typical 'book value and abnormal earnings' valuation models. Thus, overall the models appear to be relatively well specified, a feature that provides additional confidence when we turn to interpret the coefficients on the various carbon measures which represent our primary interest.

Turning to the coefficients on the various carbon emissions measures, we find strong and consistent support for the proposition that the carbon emissions data are value relevant. Specifically, focusing on the pooled model results presented in the first column of each panel, we find the coefficient on *EmitTot* reported in Panel A at -0.044 to be negative and highly significant ($p < 0.001$). Thus, consistent with expectations, the market appears to assess a valuation penalty relative to firm's total carbon emissions figure. Further, based on the magnitude of the estimated coefficient value, the magnitude of this penalty would appear to be €44 per ton.

Of greater interest, turning to Panel B, we find a negative and significant coefficient on *AllocShort* of -0.084 ($p = 0.038$). In contrast, the coefficient on *PerAlloc* at 0.019 is positive but insignificant ($p = 0.475$). Further, the test of the linear restriction reveals the difference in these coefficient estimates to be significant at the 5% level. Thus, the results are strongly supportive of H_1; the evidence indicates that the market values the portion of total emissions not covered by free allowances (*AllocShort*) but assigns a zero latent liability to the covered emissions. The estimated coefficient on *AllocShort* implies a valuation penalty of €84 per ton of uncovered emissions, a figure which represents 3.53% of market capitalization, on average, across our sample firms.

Lastly, as revealed in the final four columns of both panels of Table 4, while the basic message is consistent with that conveyed based on the pooled data, there are differences across years. To begin, the adjusted R^2s are higher for each 2007, 2008, and 2009 than for the pooled analyses, suggestive that the nature of the relation is in some regards, “year dependent”. Consistent with this suggestion, we also observe differences across the years in both the magnitude and significance of the coefficients on *EmitTot* in Panel A and *AllocShort* in Panel B. For example, the coefficient estimates (*p*-values) on *AllocShort* in Panel B are -0.026 ($p = 0.079$) for 2006, -0.061 ($p = 0.047$) for 2007, -0.189 ($p = 0.033$) for 2008, and -0.097 ($p = 0.006$) for 2009. Thus, the strength of the coefficient as assessed by its *p*-value has consistently increased throughout the study period. Further, with the exception of 2008, the magnitude of the coefficient has also increased, suggestive of an increase in the size of the assessed penalty per ton of uncovered carbon emissions. In 2006, the assessed penalty was €26 per ton, increasing to €61 per ton in 2007, and finally €97 per ton in 2009. In 2008, the assessed penalty was considerably higher at €189 per ton, consistent with the much higher market price of carbon at that time, as well as the then held anticipation of higher price going forward. Alternatively, by 2009 the price had significantly fallen relative to its high in 2008, and hence a lower assessed penalty is not unreasonable.

5.2 Cost Pass On Ability Results

Underlying the second hypothesis is the argument that the negative valuation impact documented above will be mitigated by the firm’s ability to pass the cost on to the ultimate customer. Here, we envisage that both industry wide and firm specific factors will affect this ability. At the industry level, we argue that firms in more concentrated industries will have a greater ability to pass the costs on while at the firm level, we argue that this ability will be related to a firm’s relative carbon efficiency within its industry. In brief, the results from these analyses provide consistent support for the notion that the negative valuation impact is lessened in settings where the firm’s ability to pass the cost on is argued to be greater.

5.2.1 Industry Level Measure

Beginning at the industry-level, as described in equation (3), we use Herfindahl-Hirschman (*HH*) index as a proxy for market concentration and thereby the ability of a firm within a given industry to pass on costs. The results for this analysis are reported in Table 5. Given the similarity of the patterns across years with those reported for the base model above, we restrict our attention to the results based on the pooled data reported in the first column. Here again, the coefficients on *BV* and *AE* are positive and highly significant. Further, as expected, the coefficient on *HH* is positive and significant (2.545, p = 0.033) indicating the presence of "monopoly" profits in more highly concentrated industries.

Turning to the emissions measures, the coefficient on *AllocShort* is again negative and significant (-0.098, p = 0.014) while the coefficient on *PerAlloc* is positive but insignificant (0.013, p = 0.647). Thus, the evidence once again supports a negative valuation impact for carbon emissions uncovered by permit allocations but not for those that are covered. Importantly, consistent with H_2, the coefficient on the interaction term *AllocShort*HH* is positive and significant (0.063, p = 0.052). However, from a statistical perspective, the linear restriction capturing the marginal valuation impact of *AllocShort* conditional on *HH*, $\alpha_4 + \alpha_6$ in equation (3), retains statistical significance at the 5% level even for firms in the most concentrated industries within our sample. Thus, while the results indicate that the negative valuation impact of uncovered carbon emissions is reduced in highly concentrated industries, consistent with the notion that a firm's latent carbon liability is mitigated by its carbon cost pass on ability, the reduction is incomplete. In contrast, the coefficient on *PerAlloc*HH* is positive but insignificant (0.007, p = 0.443).

5.2.2 Firm Level Measures

At the firm level, we consider two measures of relative carbon efficiency. First, we consider the firm's industry-year rank carbon efficiency as captured by the measure *Rank*. We then consider changes in the firm's relative carbon intensity over the prior two years as captured by the measure

ΔRank. The results for these analyses, based on equations (4) and (5), are presented in Panels A and B of Table 6, respectively. Given the similarity of the patterns across the study period, we again restrict our discussion to the results based on the pooled data reported in the first column of each panel. Further, here also the coefficients on *BV* and *AE* are highly significant.

Turning to the emissions measures, the coefficient on *AllocShort* is again negative and significant in both panels, while the coefficient on *PerAlloc* is positive but insignificant in each. Thus, again the evidence supports a negative valuation impact for carbon emissions uncovered by permit allocations but not for those that are covered. Importantly, consistent with H_2, the coefficients on the interaction terms *AllocShort*Rank* and *AllocShort*ΔRank* are both positive and significant. Specifically, for the model incorporating the relative carbon intensity measure *Rank* (Panel A), the coefficient on *AllocShort*Rank* is 0.101 (p = 0.037) while for the model incorporating the change in relative intensity measure *ΔRank* (Panel B) the coefficient on *AllocShort*ΔRank* is 0.026 (p = 0.069). In contrast, the coefficients on the interaction terms involving the permit allocation measure, *PerAlloc*Rank* and *PerAlloc*ΔRank*, are both insignificant. Thus, the results indicate that a firm's latent carbon liability is mitigated by its carbon cost pass on ability as reflected in its relative carbon emissions efficiency, consistent with arguments advanced by Grainger and Kolstad (2010), Fullerton and Heutel (2007), and IRRC Institute and Trucost (2006). In fact, from a statistical perspective, the linear restriction capturing the marginal valuation impact of *AllocShort* conditional on *Rank* loses statistical significance for values of *Rank* above 0.634 (i.e., the p-value on the F-test that the linear restriction $\alpha_4 + \alpha_6$ in equation (4) is equal to zero is 0.050 when *Rank* = 0.634). Thus, the results indicate that the market does not assess a valuation penalty for the sample observations ranked among the best 36.6% in terms of carbon efficiency on an industry-year percentile rank basis.

5.2.3 Composite Model Results

Finally, for completeness, we consider the composite models presented in equations (6) and (7) that incorporate both the firm level and industry level measures designed to capture a firm's cost pass on ability. The results for these analyses are presented in Table 7, with the results for the model incorporating *HH* and *Rank* presented in the first column and the results incorporating *HH* and *ΔRank* presented in the second column. Here again, the coefficient on the primary measure *AllocShort* is negative and highly significant in both models while the coefficient on *PerAlloc* is insignificant. Importantly, within the first model, the coefficient on *AllocShort*Rank* is 0.102 (p = 0.026) and the coefficient on *AllocShort*Rank*HH* is 0.010 (p = 0.076). Thus, within the context of this model, both firm level and the industry measures of a firm's carbon cost pass on ability incrementally serve to mitigate the negative valuation impact of a firm's carbon emissions. Alternatively, within the second model, the coefficient on *AllocShort*ΔRank* is 0.026 (p = 0.071) and the coefficient on *AllocShort*ΔRank*HH* is -0.018 (p = 0.083). Thus, here only the firm level measure appears to mitigate the negative valuation impact.

5.3 Global Carbon Emissions Model Results

The final hypothesis, H_3, argues that the valuation implications of a firm's carbon emissions subject to the EU ETS will differ from that of its non-EU emissions which are not subject to an implemented 'cap and trade' scheme. To test this hypothesis, as presented in equation (8), we disaggregate a firm's total global carbon emissions into its EU emissions and non-EU emissions, and then as before, its EU emissions into those covered by permit allocations (*PerAlloc*) and those not covered (*AllocShort*). We then estimate equation (9) based on the sample of 189 firm-year observations for which not only the firm's EU carbon emissions data are available but also its global carbon emissions from the CDP.

The results for this analysis are reported in Table 8. Panel A presents results for the base models while Panel B presents results for models which incorporate the firm level carbon cost pass on ability measures, *Rank* and *ΔRank*. As before, the coefficients on *BV* and *AE* are consistently positive and significant, and the adjusted R^2s for all models remain high. Further, Models 1 and 2 in Panel A indicate that results based on this subsample are comparable to those found in Table 4 based on the broader sample. For example, in Model 2, the coefficient on *AllocShort* is -0.086 (p = 0.007) while the coefficient on *PerAlloc* is 0.027 (p = 0.117).

Models 3 and 4 of Panel A then turn to consider the valuation implications of a firm's global carbon emissions as reported to the CDP. Here, Model 3 reveals that a firm's total global emissions are valuation relevant. The coefficient on *CDP Global Emissions* is -0.053 (p = 0.023). Importantly, when the total global emissions measure is disaggregated into its components (Model 4), the coefficients on *AllocShort* at -0.094 (p = 0.008) and *Non-EU Emissions* at -0.048 (p = 0.041) are both negative and significant, while the coefficient on *PerAlloc* is positive but insignificant (0.025, p = 0.169). Further, the test of the linear restriction reveals the difference in the coefficient estimates for *AllocShort* and *Non-EU Emissions* to be significant at the 1% level. Thus, the results are strongly supportive of H_3, indicating that the valuation impact of a firm's EU carbon emissions is significantly greater than that of its non-EU carbon emissions that are not subject to an implemented cap and trade system.

Finally, the results presented in Panel B indicate that a firm's carbon cost pass on ability as captured by the firm-level measure *Rank*, and to a lesser extent *ΔRank*, serves to mitigate both its EU and non-EU carbon emissions related liabilities. From Model 1, the coefficients (p-values) on *AllocShort*Rank* and *Non-EU Emissions*Rank* are 0.061 (p = 0.039) and 0.012 (p = 0.014), respectively. Alternatively, from Model 2, the coefficients (p-values) on *AllocShort*ΔRank* and *Non-EU Emissions*ΔRank* are 0.028 (p = 0.065) and 0.010 (p = 0.082), respectively.

6. Conclusion

This study examines the valuation relevance of corporate carbon emissions under the EU ETS. Following economic theory, we explicitly consider the impact of carbon emissions allowances and firms' ability to pass on the carbon compliance costs to consumers in our valuation model. Using a sample of 843 firm-year observations from the EU ETS from the period 2006 – 2009, we find that the impact of carbon emissions on firm values in the EU ETS differs in various dimensions. Specifically, we find that a firm's latent carbon liability: (1) relates to the portion of emissions that exceed free allowances within the EU ETS, (2) is mitigated by its ability to pass on the future compliance costs to consumers, with this ability related to both firm level and industry level factors, and (3) varies for carbon emissions within versus outside the EU ETS jurisdiction. Our findings are robust to different model specifications and proxy measures.

These findings have some important implications. First, they indicate that investors assess a firm's latent carbon liability within the contexts of its carbon allowances, its competitive position and relative carbon efficiency, and the relevant carbon enforcement jurisdiction. Future research in this area must, therefore, consider these factors to avoid model misspecifications and unreliable inferences. Second, they may assist securities regulators and accounting standard setters in their future policy delivery with respect to the disclosure of firms' future carbon liability. Our results indicate that investors need the following information in order to refine their estimates of latent carbon liabilities: (1) current carbon emissions at the corporate entity level, segregated by regions under different regulatory regimes; (2) the firm's carbon efficiency relative to its sector peers for each sector the company operates in; and (3) other information indicating the firm's ability to pass on increased carbon costs to consumers.

Finally, the accounting profession and standard setters are currently debating on a framework for disclosure and recognition of carbon related liability (Bebbington and Larrinaga-Gonzalez, 2008; Ertimur *et al.*, 2011, Veith *et al.*, 2009, PriceWaterhouseCooper, 2007). A central issue in this debate is the proper recognition of allocated carbon allowances. Our findings indicate that allocated carbon allowances themselves have little valuation impact, consistent with the "net approach." Our capital market evidence suggests that the "net approach" meets the relevance and faithful representation requirements while the same cannot be said for the “gross approach.” Nonetheless, since the “net approach” fails the comparability requirement, it remains to be seen what will prevail.

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Table 1 **Frequency Distribution by Country, Industry, and Year for a sample of 843 Firm-Year Observations for a Sample of European Companies**

Panel A: Frequency Distribution for the number of Observations by Country and Year

Country	**2006**	**2007**	**2008**	**2009**
Austria	4	4	4	4
Belgium	7	7	8	8
Czech Republic	10	10	10	10
Denmark	7	7	7	7
Finland	11	12	13	13
France	9	9	9	9
Germany	19	19	19	19
Greece	8	8	8	8
Ireland	2	2	2	2
Italy	11	12	14	15
Latvia	2	2	2	2
Lithuania	8	8	7	7
Luxembourg	0	1	1	1
Netherlands	2	2	3	3
Poland	11	11	12	14
Portugal	4	5	5	5
Romania	0	1	1	1
Slovenia	1	3	3	3
Spain	29	29	29	29
Sweden	10	10	10	10
UK	42	45	51	51
Total	**197**	**207**	**218**	**221**

Panel B: Frequency Distribution for the number of Firm-Year Observations by Industry Sector

Industry Sector		**# Firm-Year Observations**	
1	**Oil & Gas**		
530	Oil & Gas Producers	72	
570	Oil Equipment & Service	6	**78**
1000	**Basic Metals**		
1350	Chemicals	55	
1730	Forestry & Paper	72	
1750	Industrial Metals & Mining	57	
1770	Mining	8	**192**
2000	**Industrials**		
2350	Construction & Materials	101	
2710	Aerospace & Defense	16	
2720	General Industrials	40	
2730	Electronic & Electrical Equipment	8	
2750	Industrial Engineering	40	
2770	Industrial Transportation	2	
2790	Support Services	16	**223**

Industry Sector		**# Firm-Year Observations**	
3000	**Consumer Goods**		
3350	Automobiles & Parts	11	
3530	Beverages	29	
3570	Food Producers	62	
3720	Household Goods & Home Construction	16	
3740	Leisure Goods	2	
3760	Personal Goods	8	
3780	Tobacco	8	**136**
4000	**Health Care**		
4530	Health Care Equipment & Services	4	
4570	Pharmaceuticals & Biotechnology	28	**32**
5000	**Consumer Services**		
5330	Food & Drug Retailers	4	
5550	Media	4	
5750	Travel & Leisure	10	**18**
7000	**Utilities**		
7530	Electricity	76	
7570	Gas, Water & Multiutilities	76	**152**
8000	**Financials**		
8770	Financial Services	4	**4**
9000	**Technology**		
9530	Software & Computer Services	4	
9570	Technology Hardware & Equipment	4	**8**

Table 2 Descriptive Statistics for a Sample of 843 Firm-Year Observations for a Sample of European Companies

Panel A: Firm Characteristics for the pooled sample of 843 firm-year observations

Variable	**Mean**	**Median**	**Std Dev**	**1st Percentile**	**99th Percentile**
V	7.225	1.163	17.626	0.010	105.030
BV	3.159	0.485	1.718	0.010	43.170
E	0.569	0.024	7.411	-0.710	9.220
AE	0.224	-0.043	8.221	-1.830	5.170
LEV	0.610	0.633	0.179	0.150	0.920
CAPINT	0.397	0.395	0.200	0.010	0.830
CAPEX	0.096	0.060	0.118	0.010	0.560

Panel B: Carbon Emissions Descriptive Statistics (in million tons)

Measure	**Mean**	**Median**	**Std Dev**	**1st Percentile**	**99th Percentile**
Total Emissions	5.247	0.145	26.001	0.000	78.550
Permits allocated	2.209	0.106	9.787	0.000	38.780
Allocation shortfall	3.039	0.028	16.818	-0.041	51.140
Allocation Proportion	1.022	0.598	1.692	0.140	4.670

Variable definitions: In Panel A, *V* is the firm's market capitalization, *BV* is its book value, *E* is its earnings, *AE* is abnormal earnings, *LEV* is leverage measured by the debt-to-assets ratio, *CAPINT* is capital intensity measured as net property, plant, and equipment as a proportion of total assets, and *CAPEX* is capital expenditure measured as total capital expenditure as a proportion of sales. All figures have been converted to Euros. For *V*, *BV*, *E*, and *AE*, figures are in € billions. In Panel B, the figures represent total carbon emissions, permits allocations, and allocation shortfall defined as the difference between a firm's total carbon emissions and its permit allocation. The allocation proportion is equal to the permits allocation divided by total emissions

Table 3 Descriptive Statistics for a Sample of 189 Firm-Year Observations for a Sample of European Companies with both EU and CDP carbon emissions data

Panel A: Firm Characteristics

Variable	Mean	Median	Std Dev	1st Percentile	99th Percentile
V	15.739^{***}	5.286	23.325	0.311	92.232
BV	9.561^{***}	3.567	13.504	0.159	48.130
E	1.451	0.210	16.209	-0.417	8.447
AE	0.756	-0.065	11.307	-1.450	7.210
LEV	0.663^{***}	0.685	0.134	0.421	0.918
CAPINT	0.307^{***}	0.288	0.243	0.020	0.810
CAPEX	0.074^{**}	0.051	0.092	0.020	0.430

Panel B: Carbon Emissions Descriptive Statistics (in million tons)

Measure	Mean	Median	Std Dev	1st Percentile	99th Percentile
Total Emissions	9.939^{**}	0.243	33.813	0.000	78.546
Permits allocated	3.593^{*}	0.189	10.379	0.000	38.266
Allocation shortfall	6.345^{**}	0.056	23.934	-0.037	47.900
Allocation Proportion	0.843	0.575	1.147	0.230	2.460

Variable definitions: In Panel A, *V* is the firm's market capitalization, *BV* is its book value, *E* is its earnings, *AE* is abnormal earnings, *LEV* is leverage measured by the debt-to-assets ratio, *CAPINT* is capital intensity measured as net property, plant, and equipment as a proportion of total assets, and *CAPEX* is capital expenditure measured as total capital expenditure as a proportion of sales. All figures have been converted to Euros. For *V*, *BV*, *E*, and *AE*, figures are in € billions. In Panel B, the figures represent total carbon emissions, permits allocations, and allocation shortfall defined as the difference between a firm's total carbon emissions and its permit allocation. The allocation proportion is equal to the permits allocation divided by total emissions

***, **, * The mean value for the measure based on the 189 firm-year observations as reported in Table 3 is significantly different from the mean value for the measure based on the 843 firm-year observations as reported in Table 2 at the 1%, 5%, and 10% levels, respectively.

Table 4 Valuation Model Regression Results Based on a Sample of 843 Firm-Year Observations for European Companies over the Period 2006 – 2009

Panel A: Regression Model Results based on the Pooled Sample of 843 Firm-Year Observations

Variable	**Pooled**	**2009**	**2008**	**2007**	**2006**
Intercept	1.194	0.862	2.095	0.921	0.982
	(< 0.001)	(0.058)	(0.002)	(0.198)	(0.250)
BV	1.116	1.359	1.587	1.340	1.200
	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)
AE	7.048	5.405	6.525	9.488	8.076
	(< 0.001)	(< 0.001)	(<0.001)	(< 0.001)	(< 0.001)
EmitTot	***-0.044***	***-0.077***	***-0.105***	*-0.018*	-0.013
	(<0.001)	***(<0.001)***	***(0.025)***	*(0.071)*	(0.104)
Adj R^2	0.809	0.888	0.859	0.859	0.800

Panel B: Results by Year for the Disaggregated Model

Variable	**Pooled**	**2009**	**2008**	**2007**	**2006**
Intercept	1.212	1.020	2.191	0.914	0.978
	(< 0.001)	(0.024)	(0.001)	(0.203)	(0.252)
BV	1.522	1.393	1.633	1.348	1.236
	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)
AE	7.038	5.510	6.538	9.493	8.189
	(< 0.001)	(< 0.001)	(< 0.001)	(<0.001)	(< 0.001)
AllocShort	***-0.084***	***-0.097***	***-0.189***	***-0.061***	*-0.026*
	(0.038)	***(0.006)***	***(0.033)***	***(0.047)***	*(0.079)*
PerAlloc	0.019	0.028	0.035	0.018	0.051
	(0.475)	(0.304)	(0.235)	(0.622)	(0.302)
Adj R^2	0.809	0.892	0.860	0.858	0.800

Variable definitions: *V* is the firm's market capitalization, *BV* is its book value, *AE* is abnormal earnings, *EmitTot* is the firm's total carbon emissions as reported to the EU, *PerAlloc* is the firm's permit allocation, and *AllocShort* is the firm's allocation shortfall, is measured as the difference between *EmitTot* and *PerAlloc*.

p-values (reported in parenthesis) are two-tailed and based on standard errors clustered by firm, industry, and year (as appropriate). Reported intercept estimates are scaled by 1,000,000.

Table 5 Valuation Model Regression Results for the Sample Conditioned on Industry Concentration measured by the Herfindahl-Hirschman (HH) Index

Variable	**Pooled**	**2009**	**2008**	**2007**	**2006**
Intercept	0.461	2.331	0.987	0.446	2.537
	(0.405)	(0.100)	(0.335)	(0.680)	(0.842)
BV	0.968	1.101	1.684	1.146	1.297
	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)
AE	7.564	7.018	6.507	8.484	9.292
	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)
HH	***2.545***	*1.245*	***3.924***	*4.301*	***2.275***
	(0.033)	*(0.057)*	***(0.035)***	*(0.089)*	***(0.040)***
AllocShort	***-0.098***	***-0.132***	***-0.150***	***-0.105***	*-0.077*
	(0.014)	***(0.027)***	***(0.029)***	***(0.047)***	*(0.071)*
PerAlloc	0.013	0.015	0.020	0.015	*0.033*
	(0.647)	(0.497)	(0.254)	(0.249)	*(0.089)*
AllocShort*HH	*0.063*	*0.050*	*0.062*	*0.047*	*0.043*
	(0.052)	*(0.068)*	*(0.059)*	*(0.082)*	*(0.097)*
PerAlloc*HH	0.007	-0.001	0.002	0.002	0.003
	(0.443)	(0.323)	(0.340)	(0.731)	(0.828)
Adj R^2	0.806	0.865	0.869	0.859	0.800

Variable definitions: *V* is the firm's market capitalization, *BV* is its book value, *AE* is abnormal earnings, *EmitTot* is the firm's total carbon emissions as reported to the EU, *PerAlloc* is the firm's permit allocation, *AllocShort* is the firm's allocation shortfall, is measured as the difference between *EmitTot* and *PerAlloc*, and *HH* is the Herfindahl-Hirschman index.

p-values (reported in parenthesis) are two-tailed and based on standard errors clustered by firm, industry, and year (as appropriate). Reported intercept estimates are scaled by 1,000,000.

Table 6 Valuation Model Regression Results for the Sample Conditioned on Relative Carbon Emissions Profile

Panel A: Conditioned on Industry-Year Carbon Emission Percentile Rank

Variable	**Pooled**	**2009**	**2008**	**2007**	**2006**
Intercept	2.510 (< 0.001)	2.050 (0.114)	1.287 (0.255)	2.383 (0.057)	3.545 (0.023)
BV	0.969 (< 0.001)	0.956 (< 0.001)	1.739 (< 0.001)	1.157 (< 0.001)	1.381 (< 0.001)
AE	7.661 (< 0.001)	6.356 (< 0.001)	5.192 (< 0.001)	8.282 (< 0.001)	9.408 (< 0.001)
Rank	-0.034 (0.211)	*0.039* *(0.087)*	0.009 (0.700)	-0.021 (0.402)	-0.016 (0.382)
AllocShort	***-0.119*** ***(0.017)***	***-0.136*** ***(0.018)***	***-0.164*** ***(0.025)***	***-0.115*** ***(0.039)***	*0.064* *(0.055)*
PerAlloc	0.016 (0.697)	0.019 (0.428)	0.015 (0.480)	0.027 (0.265)	*0.043* *(0.077)*
AllocShort*Rank	***0.101*** ***(0.037)***	***0.105*** ***(0.015)***	***0.147*** ***(0.009)***	*0.120* *(0.080)*	*0.043* *(0.065)*
PerAlloc *Rank	0.002 (0.773)	0.005 (0.390)	0.003 (0.547)	0.001 (0.730)	0.001 (0.643)
Adj R^2	0.803	0.794	0.874	0.860	0.802

Panel B: Conditioned on Two-Year Prior Change in Emissions Percentile Rank (Model 2)

Variable	**Pooled 2008 & 2009** (n = 399)	**2009** (n = 205)	**2008** (n = 194)
Intercept	1.597 (0.006)	2.814 (0.009)	1.026 (0.427)
BV	1.208 (< 0.001)	1.153 (< 0.001)	1.567 (< 0.001)
AE	6.366 (< 0.001)	6.720 (< 0.001)	5.785 (< 0.001)
ΔRank	***0.006*** ***(0.031)***	***0.006*** ***(0.012)***	***0.009*** ***(0.001)***
AllocShort	***-0.128*** ***(0.014)***	***-0.103*** ***(0.019)***	***-0.142*** ***(0.002)***
PerAlloc	0.015 (0.643)	0.016 (0.514)	0.019 (0.401)
AllocShort* ΔRank	*0.026* *(0.069)*	*0.023* *(0.087)*	*0.031* *(0.058)*
PerAlloc * ΔRank	0.001 (0.756)	0.000 (0.896)	0.001 (0.743)
Adj R^2	0.829	0.788	0.856

Variable definitions: *V* is the firm's market capitalization, *BV* is its book value, *AE* is abnormal earnings, *EmitTot* is the firm's total carbon emissions as reported to the EU, *PerAlloc* is the firm's permit allocation, *AllocShort* is the firm's allocation shortfall, is measured as the difference between *EmitTot* and *PerAlloc*, *Rank* is the firm's industry-year percentile rank for its total carbon emissions scaled by sales, and *ΔRank* is the two year change in *Rank*.

p-values (reported in parenthesis) are two-tailed and based on standard errors clustered by firm, industry, and year (as appropriate). Reported intercept estimates and the coefficients on *Rank* and *ΔRank* are scaled by 1,000,000.

Table 7 Valuation Model Regression Results for the Sample Conditioned on Relative Carbon Emissions Profile and Market Concentration

Variable	**Pooled**	**Variable**	**Pooled**
Intercept	1.551	**Intercept**	1.527
	(0.048)		(0.050)
BV	0.973	***BV***	0.927
	(< 0.001)		(< 0.001)
AE	7.646	***AE***	7.717
	(< 0.001)		(< 0.001)
Rank	-0.039	***ΔRank***	***0.006***
	(0.205)		***(0.050)***
HH	***3.979***	***HH***	*3.428*
	(0.021)		*(0.052)*
AllocShort	***-0.138***	***AllocShort***	***-0.095***
	(0.016)		***(0.016)***
PerAlloc	0.013	***PerAlloc***	-0.004
	(0.780)		(0.926)
AllocShort*Rank	***0.102***	***AllocShort*ΔRank***	*0.026*
	(0.026)		*(0.071)*
PerAlloc *Rank	0.001	***PerAlloc *ΔRank***	0.002
	(0.864)		(0.788)
AllocShort*Rank*HH	*0.010*	***AllocShort*ΔRank*HH***	*-0.018*
	(0.076)		*(0.083)*
PerAlloc *Rank*HH	0.001	***PerAlloc *ΔRank*HH***	0.000
	(0.871)		(0.982)
Adj R^2	0.803	***Adj*** R^2	0.804

Variable definitions: *V* is the firm's market capitalization, *BV* is its book value, *AE* is abnormal earnings, *EmitTot* is the firm's total carbon emissions as reported to the EU, *PerAlloc* is the firm's permit allocation, *AllocShort* is the firm's allocation shortfall, is measured as the difference between *EmitTot* and *PerAlloc*, *HH* is the Herfindahl-Hirschman index, *Rank* is the firm's industry-year percentile rank for its total carbon emissions scaled by sales, and *ΔRank* is the two year change in *Rank*.

p-values (reported in parenthesis) are two-tailed and based on standard errors clustered by firm, industry, and year (as appropriate). Reported intercept estimates and the coefficients on *Rank* and *ΔRank* are scaled by 1,000,000.

Table 8 Valuation Model Regression Results Based on a Sample of 189 Firm-Year Observations for European Companies with both Global and EU Emissions Data

Panel A: Baseline (Benchmark) Regression Model Results

Variable	**Model 1**	**Model 2**	**Variable**	**Model 3**	**Model 4**
Intercept	1.637	1.565	**Intercept**	1.738	1.657
	(0.235)	(0215)		(0.190)	(0.182)
BV	1.249	1.315	***BV***	1.411	1.460
	(< 0.001)	(< 0.001)		(< 0.001)	(< 0.001)
AE	5.767	6.113	***AE***	5.526	5.808
	(<0.001)	(< 0.001)		(< 0.001)	(< 0.001)
EmitTot	***-0.061***	---	***CDP Global Emissions***	***-0.053***	---
	(0.018)			***(0.023)***	
AllocShort	---	***-0.086***	***AllocShort***	---	***-0.094***
		(0.007)			***(0.008)***
PerAlloc	---	0.027	***PerAlloc***	---	0.025
		(0.117)			(0.169)
			Non-EU Emissions	---	***-0.048***
					(0.041)
Adj R^2	0.887	0.905		0.895	0.909

Panel B: Regression Model Results including Non-EU Emissions

Variable	**Model 1**	**Variable**	**Model 2**
Intercept	-2.605	**Intercept**	1.387
	(0.846)		(0.087)
BV	1.043	***BV***	0.848
	(< 0.001)		(< 0.001)
AE	7.643	***AE***	6.550
	(< 0.001)		(< 0.001)
Rank	0.051	***ΔRank***	***0.004***
	(0.154)		***(0.037)***
AllocShort	***-0.097***	***AllocShort***	***-0.102***
	(0.038)		***(0.014)***
PerAlloc	0.030	***PerAlloc***	0.028
	(0.887)		(0.262)
Non-EU Emissions	***-0.035***	***Non-EU Emissions***	***-0.046***
	(0.033)		***(0.034)***
AllocShort * Rank	***0.061***	***AllocShort * ΔRank***	*0.028*
	(0.039)		*(0.065)*
PerAlloc * Rank	-0.010	***PerAlloc * ΔRank***	-0.029
	(0.721)		(0.264)
Non-EU Emissions * Rank	***0.012***	***Non-EU Emissions * ΔRank***	*0.010*
	(0.014)		*(0.082)*
Adj R^2	0.976	***Adj R^2***	0.974

Variable definitions: *V* is the firm's market capitalization, *BV* is its book value, *AE* is abnormal earnings, *EmitTot* is the firm's total carbon emissions as reported to the EU, *PerAlloc* is the firm's permit allocation, *AllocShort* is the firm's allocation shortfall, is measured as the difference between *EmitTot* and *PerAlloc*, *Non-EU Emissions*, the firm's carbon emissions outside the EU, is measured as the difference between total emissions reported to the EU (*EmitTot*) and total emissions reported to the CDP (*CDP GlobalEmissions*), *Rank* is the firm's industry-year percentile rank for its total carbon emissions scaled by sales, and *ΔRank* is the two year change in *Rank*.

p-values (reported in parenthesis) are two-tailed and based on standard errors clustered by firm, industry, and year (as appropriate). Reported intercept estimates and the coefficients on *Rank* and *ΔRank* are scaled by 1,000,000.