How does the stock market reward companies with a lower carbon footprint?

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Abstract

We investigate whether company carbon emissions appear to be a priced risk factor on the stock market. We do this by constructing a "*CARNBON*" factor, which we then test using 25 size-bm portfolios, and 48 industry portfolios. We find that for the US market, this *CARBON* factor improves the test efficiency of the Fama-French factor model in terms of a GRS test, and our industry results exhibit factor loadings that might reasonably be expected. We then form portfolios that are long in low carbon firms (LCF) and short in high carbon firms (HCF), where we find that the addition of our *CARBON* factor suggests that LCF have a lower cost of capital. Finally, we employ an Ohlson type valuation model which shows that carbon emissions are inversely related to valuation. This result is striking, and insensitive to the choice of deflator used in the valuation model. The result is consistent with lower carbon firms either having a lower cost of capital, or having superior long-run cash flow prospects, or a combination of both.

Keywords: asset pricing, multi factor models, carbon pricing, Ohlson valuation model, cost of capital

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1 Introduction

The reform of business practices is vital for meeting critical target reductions in greenhouse gas emissions. As, in theory, the dominant strategic objective for firms is shareholder value maximisation, it is relevant to understand whether stock markets do take account of the size of firms' carbon footprints. If companies with lower carbon emissions than their peers are rewarded, then managers are enabled to develop carbon reduction strategies, insofar as they do not conflict with shareholder interests. However, as Misani and Pogutz (2015) remind us, it is important to investigate not only whether financial performance is enhanced by lower company carbon emissions, but also specifically how this is achieved.

In this paper, our first goal is to address the question whether carbon emissions are recognised as a risk on the stock market. To examine this, we construct a measure of carbon performance for all firms, based on carbon emissions per unit of sales. Then we test whether carbon performance is priced as a risk factor, and find evidence that it is. We then show that there appears to be a cost of capital effect, with low carbon firms (LCF)[1] having a lower cost of capital than high carbon firms (HCF). Our second goal is to examine whether firms' carbon performance is reflected in their market valuations, and we find that the degree of carbon emission appears to be priced by markets, with the market value of the firm decreasing in the degree of carbon emission.

Our study complements the research of Misani and Pogutz (2015) who also investigate how the carbon strategy of firms affects their financial performance, but instead of applying Tobin's Q to approximate firm value as they do, we employ an Ohlson type valuation model. While Misani and Pogutz (2015) consider the extent to which the impact of firm carbon strategy on firm value is attributable to carbon performance per se, and to what extent moderated by environmental management (i.e. firm initiatives to reduce emissions), we give sole attention to carbon performance and study firms exclusively within one national boundary, which limits the degree of institutional heterogeneity. Our geographical focus is the USA, a country where Misani and Pogutz (2015) find carbon performance has a statistically significant effect, but environmental management disclosure does not.

Our definition of carbon performance also differs from Misani and Pogutz (2015), for while they consider both direct emissions by a company (known as Scope 1), and their emissions resulting from purchased electricity (known as Scope 2), we focus solely on direct emissions. There is a case for using each approach. By including Scope 2, there is recognition the some of the demand for electricity and its associated carbon emissions is derived from company activities, and clearly when a price is put on carbon, a company's dependence on purchased electricity is financially relevant. On the other hand, there is an accounting challenges in determining the precise carbon content of the electricity consumed by firms. In this paper we choose to work solely with direct emissions, not only because of this particular accounting difficulty, nor the fact that there is no mandatory carbon pricing in the USA,

[1] Throughout this paper, we define low carbon firms (LCF) as those with a lower level of carbon emissions per sale, in effect, having a higher carbon performance than their peers; while high carbon firms (HCF) are defined as a high level of carbon emissions per sale and therefore with low carbon performance.

but also by focusing on direct emissions we give greatest attention to the largest original sources of carbon emissions, where change is primarily required for developing a low carbon economy. Therefore, precisely we are seeking to investigate how the stock market might have a role in changing the strategy of direct carbon emitters.

The rest of the paper is structured as follows. In section 2 we consider how carbon performance can be construed as a financial risk. We review how this might be assessed using first an extension of the Fama–French model, and secondly by examining how carbon performance might affect firm value. We also establish our hypotheses. Section 3 describes the data and methodology while Section 4 presents our results. Finally, we draw conclusions in Section 5.

2. Review of the financial risk of carbon emissions

2.1 Carbon and corporate risk

Most firms operate in a highly competitive environment, and so consequently business practices that reduce carbon emissions, even if they are responsibly motivated, need to be financially sound. Oppositely, if firms neglect to consider their carbon performance, and so fail to take up potential profit generating opportunities associated with reduced emissions, they could lose out to their competitors (Ziegler et al. 2011). As this is a relatively new area of firm strategy, it still remains an open question whether companies are able to make optimal decisions regarding carbon performance, and whether financial markets recognise materiality here.

Busch and Hoffmann (2007) provide a detailed discussion on the ways in which carbon constraints might be a corporate risk, and classify the possibilities as relating to either an input dimension or an output dimension. Their input dimension considers dependency on carbon intensive fuels and factors that might influence their price such as relative scarcity, domestic taxes and geopolitics. Their output dimension gives specific attention to how concern about climate change might result in additional regulations, alterations in consumer preferences, as well as the likely physical effects of climate change to impact on business operations. In this paper we do not study the possible physical effects of climate change on business, but concentrate on firms' carbon performance, their carbon emissions per unit of sales value, which we also refer to as their carbon footprint. Evidently, a firm's carbon footprint might be influenced by both the input dimension, with factors affecting the price of energy, and the output dimension in so far as both government regulation and moral suasion might cause companies to consider reducing their emissions.

Busch and Hoffmann (2011) make a useful distinction between *operational efficiency* and *stakeholder action* in mediating the link between firm strategies relating to climate change and financial performance. Drawing on the literature of Porter and Van der Linde (1995a,b), they note that by giving attention to reducing negative environmental effects, it can be possible for a firm to improve its *operational efficiency* and so lower its costs. For example, if a government were to introduce a price on carbon, this might motivate companies to seek new ways to improve its energy efficiency. The relevance of *stakeholder action* is explained in the literature centred on understanding how corporate social performance (CSP) translates into corporate financial performance (CFP) (Barnett, 2007). Mitchell, Agle and Wood (1997) argue that a stakeholder's salience to management, depends on the degree to which they have power, legitimacy, and urgency. Consequently, Freeman et al. (2008) classifies stakeholders as either primary, if they hold power, legitimacy, and urgency, and secondary if stakeholders have legitimacy but lack power and urgency to enforce claims. Typically, primary stakeholders are identified as those which have an exchange relationship with the company, for example, employees, customers and suppliers; secondary stakeholders are those who are concerned about company activities apart from exchange, for example they may be troubled by the deleterious effects a company has on the environment or human rights. Hillman and Keim (2001) suggest that only engagement with primary stakeholders can enhance competitive advantage, by making links with employees, customers and suppliers less transactional and more relational. However, Godfrey (2005) and Godfrey et al. (2009) argue that although strategies that target primary stakeholders can create valuable exchange capital, engagement with secondary stakeholders also is relevant in building moral capital that has reputational value. Others also emphasise the importance of legitimacy in establishing a licence to operate (Chiu and Sharfman, 2011).

How do *operational efficiency* and *stakeholder action* relate to the financial impact of carbon performance? With regard to operational efficiency, notably during the period of our study (2002-2012), firms in the US were not subject to any nationwide government carbon reduction policy, in the form of carbon pricing or other types of regulation, and therefore in contrast to firms based in many other industrialised economies, US firms did not have the Porter and Van der Linde prompt to raise energy efficiency. The reason for the difference is because the US did not ratify the Kyoto Protocol when other countries did. The Kyoto Protocol was the first international agreement attempting to curb emissions of greenhouse gases, settled in December 1997 and coming into effect in 2005. The Protocol required all Annex I[2] countries to meet obligations of greenhouse gas (GHG) reductions from 2008 to 2012 by an average of 6% - 8% below 1990 levels, and it had been intended that the US reduce its emissions by 7% from 1990 levels. However, although the US administration had been instrumental in the design of the Protocol, particularly influential in making the case for carbon markets (Calel, 2013), there was a failure to ratify the Protocol following a change in the US administration in 1999.[3] As a result, US firms were not legislatively bound to reduce their carbon footprint, thereby giving them a potential competitive advantage over firms based in economies where ratification had been completed. Nonetheless, there have been voluntary initiatives adopted by some US firms, the most notable being the Regional Greenhouse Gas Initiative (RGGI). Discussions for this began in 2003 with the first compliance period for reducing carbon emissions starting in 2009 for the electric power sector in nine Northeastern and Mid-Atlantic states; these are estimated to be 7% of all US emissions in 2010 (EDF and IETA, 2013). Other firms also might be motivated to improve their operational efficiency either if they expect future legislation or as a consequence of stakeholder action.

As outlined above, research on corporate social responsibility has found that response to stakeholder action can raise the value of the firm. This can be by promoting change in business practices and by increasing reputational value, an intangible asset. Nevertheless, it remains an open question how influential stakeholder pressure has been in changing company strategy on climate change particularly. It might be argued that the susceptibility of firm specific stakeholder pressure is less than

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[2] Annex I countries include most industrialized countries and some central European economies in transition. List can be found in Annex B of the Protocol. See Kyoto Protocol To The United Nations Framework Convention On Climate Change, United Nations Framework Convention on Climate Change. Website download, http://unfccc.int/key_documents/kyoto_protocol/items/6445.php

[3] Signing the treaty is optional, implying an intention to ratify the Protocol, while ratification means that Annex I parties have agreed to control GHG emissions in accordance with the Protocol. http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php

for other concerns because climate change is a global pollution problem, although energy companies and high energy users may be exposed to some citizen pressure. However, shareholders also are stakeholders, and there has been pressure from investor based groups (e.g. Investor Network on Climate Risk, Institutional Investors Group on Climate Change) for companies to disclose their carbon footprint, in order to ascertain the risk to assets, and to embolden strategic change to lessen any risk. Therefore it is relevant to have a better understanding of how a firm's carbon footprint may expose it to greater financial risk.

2.2 Asset pricing and risk factors

The asset price of a firm should theoretically be the present value of its future cash flows, discounted at the appropriate cost of capital. Therefore the stock market value of the firm's equity[4] is given by:

$$V_t = \sum_{t=1}^{t=\infty} \frac{C_t}{(1+r_e)^{\tau}} \tag{1}$$

where C_t is the expected cash flow in year t, and r_e is the rate of return required by the shareholders. From the firm's point of view, r_e is their cost of equity capital.

The risk a shareholder holds is the potential volatility of a company's value, and this risk can be categorised as either firm-specific (also known as non-systematic risk) affecting a particular company's cash flows, or it can be systematic risk (also known as market risk). An investor can minimise firm-specific risk by holding a diversified portfolio but systematic risk is unavoidable as it can affect all assets at the same time although to a variable degree. It is normally associated with macro-economic conditions, with those more exposed to macro-economic shocks having a higher market risk. Financial stocks, highly leveraged firms, and capital goods manufacturers tend to be within this category, while utilities and supermarkets typically have a relatively low exposure. Investors want a higher premium in return for accepting a higher systematic risk, so companies with greater exposure to systematic risk have a higher cost of capital, *ceteris paribus*.

The Capital Asset Pricing Model (CAPM) was developed to determine the required return on any stock, r_e, given its exposure to systematic risk. The CAPM suggests that r_e can be determined by equation (2), where r_f the risk free rate, r_m is the expected return on the market as a whole, and its volatility in relation to the market is measured by the stock's beta, β_e.

$$r_e = r_f + \beta_e(r_m - r_f) \tag{2}$$

However, there is considerable debate regarding the most appropriate asset pricing model, with CAPM criticised for having insufficient explanatory power as it assumes that there is only one systematic risk factor, the exposure to which is captured by the beta (β_e). Alternative models to the

[4] Firms can be valued in various ways, for example, at the enterprise level (that is to say, the combined value of the firm's debt and equity) or at the equity or shareholder level (which involves valuing firm level cash flows at the equity cost of capital), but properly calculated the results are always equivalent (Lundholm and O'Keefe, 2001). In this paper, the equity level is the focus, purely because the models employed in this paper have originated at this level.

basic CAPM in (2) have been suggested, but all models share the same fundamental hypothesis that with diversified portfolios, only systematic risk affects expected returns. It follows that the higher the systematic risk exposure, the higher the expected return to compensate for the risk.

One of the most notable alternatives to the CAPM is the Fama-French three factor model (Fama and French, 1993). They argue that returns can be more fully explained by not only considering market volatility but also (a) the size of the company (historic evidence indicates that small firms (small caps) have higher returns than large firms) and (b) the ratio of accounting book value to stock value (since those with a high ratio, value stocks, tend to outperform growth stocks with a low ratio). Equation (3) gives the Fama–French model to explain returns where SMB refers to "Small (market capitalization) Minus Big", and HML denotes "High (book-to-market ratio) Minus Low"

$$r_e = r_f + \beta_e(r_m - r_f) + \beta_s SMB + \beta_v HML \qquad (3)$$

In this model SMB and HML are proxies for unobservable systematic risk factors. Other models consider further factors that might influence returns, but in all cases the motivation is similar, in that added factors capture some element of systematic risk, not captured in the CAPM, with the degree of factor exposure varying between firms. For example, the Carhart four factor model also includes a Momentum effect (Carhart, 1997). Pastor and Stambaugh (2003) develop a liquidity factor, while Chen, Zhang and Novy-Marx (2011) construct investment and profitability factors, and Mouselli, Jaafar, and Goddard (2013) an accrual quality factor. Today with climate change, and the mitigation effects relating to reducing emissions being relevant to all firms, it is apposite to test whether a firm's carbon performance is now also a risk factor. This leads to our first Hypothesis:

H1: *Carbon emissions represent an exposure to a systematic risk factor and can add greater explanatory power to the Fama-French SMB and HML factors and are therefore a priced risk factor.*

The attention given to asset pricing models does not mean that markets are indifferent to firm-specific risk. Clearly this is also important when investors pick stocks for their portfolio, but instead of being reflected in the expected cost of capital, specific risks are manifested in expected future cash flows. Consequently, the firm-specific risk of any carbon performance impacts will show up as positive or negative impacts in the expected cash flows, but will not influence the expected cost of capital (see Gregory and Whittaker, 2013 for further explanation).

It is not difficult to see why a company's carbon strategy may have both cash flow and cost of capital effects. For example, a firm might conceivably reduce its carbon footprint by improving its energy efficiency, with the following financial consequences. First, it gives the firm a lower exposure to energy prices, and therefore we might reasonably expect it to have a lower exposure to a systematic risk factors. Therefore it may have a lower cost of capital and a result of this strategy. Second, if this strategy leads to consumer approval, it might also enjoy higher cash flows as well. These cash flow effects could show up either in the form of higher profitability immediately, or in the form of superior long run growth prospects as its reputational value rises and more consumers switch to its products. The net effect will be that both numerator and denominator in (1) will change. Third, such a strategy also could diminish firm-specific risk by reducing the company's vulnerability to a government

introduction of carbon pricing in the future. Once again this would change the numerator as expected cash flows would be increased by the reduction in firm-specific risk. Therefore firm value can be enhanced by (i) a lower cost of capital, (ii) expectations of growth in cash flows, and (iii) a lower probability of cash flow shocks.
Much of the literature that has investigated the financial performance of corporate social responsibility strategies has focused on stock returns (see Renneboorg, Ter Horst and Zhang, 2008), and more recently Edmans (2011) used a portfolio-based analysis to show that one measure of CSP (employee satisfaction) is positively associated with US stock returns. With regard to carbon performance, Ziegler et al. (2011) focus on stock returns, but relate them not to carbon footprint levels, but to the degree of company disclosure on their climate change strategy. They compared US firms with EU firms and found that the financial performance of firms with a higher level of disclosure was slightly more positive in regions and periods with higher levels of institutional pressure. However, Gregory and Whittaker (2013) argue that a focus on stock returns to consider the financial performance of corporate socially responsible strategies can be problematic because it obfuscates any cost of capital effects. For example, if lower CSP (or in our case, lower carbon emissions) are associated with a lower systematic risk, then stock returns consequently might be lower, even though firm value is enhanced. Some studies have investigated cost of capital effects, for example, Sharfman and Fernando (2008) show for their sample that a firm's beta is a declining function of its degree of environmental risk management, suggesting that firms that invest in this form of risk management enjoy a lower cost of equity. However, Gregory, Tharyan and Whittaker (2014) investigating the financial implications of CSP, find that with the exception of company environmental strategies, most socially responsible strategies are not associated with a lower cost of equity capital, once the industry a firm operates in is taken into account.

Studies that implement the firm value approach (including Misani and Pogutz, 2015), typically proxy firm value by using Tobin's Q. This is the ratio of the market value of a company to the replacement value of the firm's assets, proposed by Tobin (1969). It has strength in making a connection between stock market values and the market for goods and services. However, it also has weaknesses in that it is an incomplete measure of firm value (Gregory and Whittaker 2013) for reasons we discuss below. Nonethelss, there are a number of studies that focus on Q. Dowell et al. (2000) find that US-based firms with stringent environmental standards show evidence of higher firm values (proxied by Tobin's Q). Konar and Cohen (2001) also adopt Tobin's Q, but break it down into tangible and intangible asset values. They report a positive relationship between corporate environmental performance and their intangible asset values for manufacturing firms in the S&P 500. Busch and Hoffmann (2011) studied firm-level financial performance relating to both carbon performance and carbon reduction management, the approach also adopted by Misani and Pogutz (2015). Busch and Hoffmann (2011) use three measures of financial performance, including Tobin's Q, but also stock returns (ROE) and the accountancy measure, return on assets (ROA) firm value). They obtain no significant results for ROA and ROE, but find a highly significant inverse relationship between a firm's Tobin's Q and its carbon intensity, suggesting that a lower carbon footprint is recognised on the stock market. Misani and Pogutz (2015) find that there is the inverse U –shaped relationship between carbon performance and firm value, as measured by Tobin's Q, for firms that have serous carbon reduction policies. This result contrast with that found by Barnett and Salomen (2012) which relates CSP to ROA.

In this paper we follow Gregory and Whittaker (2013) in employing a residual income model based on the Peasnell (1982) or Ohlson (1995) framework as implemented in Barth, Beaver and Landsman (1992) and Barth, Beaver and Landsman (1998). This model, as explained in Gregory and Whittaker (2013) can estimate more precisely the value effects of CSP, while remaining consistent with market prices reflecting the expected present value of future cash flows and profits. Using such a model, they show that for the US market, firms' social performance appears to be positively valued by markets. We therefore construct our second hypothesis to test whether this result stands when we focus solely on carbon performance. Consequently, our second hypothesis is as follows:

H2: Higher carbon *performance is related to higher firm value.*

3 Methodology and Data

3.1 Carbon emission data

Our carbon emission data is derived from Trucost, a natural capital data provider; they collect and collate disclosed natural capital data from companies, including quantitative environmental impact data. For data relating to carbon emissions, Trucost works with CDP (formerly known as the Carbon Disclosure Project). We adopt the Trucost definition of carbon footprint, which is based on the measurement of the firms' carbon emissions deflated by sales. However, Trucost company carbon emission data has three categories, which are consistent with the three scopes defined in 'The Greenhouse Gas (GHG) Protocol', the definitive corporate accounting and reporting standard for GHGs.[5] In this research, as the basic measure for firms' carbon performance (CP), we take into account solely those carbon emissions directly emitted by the company (this is within the scope 1 emission, excluding other GHGs) and therefore use what Trucost denominate as the carbon Footprint (CF), i.e. direct carbon emissions measured in tonnes and divided by the company's sales (in terms of billion dollars). As to our choice, we realise that there is a trade-off in using any measure, but our main focus is to concentrate on the direct emissions produced by the companies themselves, and to simplify by considering solely the major source of GHGs which are carbon dioxide emissions.

[5] The GHG Protocol was established by World Resources Institute and World Business Council on Sustainable Development to set global standards on measuring, reporting and managing greenhouse gas emissions. It classifies GHGs into three different scopes. Scopes 1 and 2 are carefully defined in the Standard to ensure there are not two or more companies which account for emissions in the same scope to avoid double counting. Scope 1 refers to the Direct GHG Emissions. "Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment." Scope 2 involves Electricity Indirect GHG Emissions. "Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated." Scope 3 includes Other Indirect GHG Emissions. "Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company, but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services."

3.2 Construction of the *CARBON* factor

To construct the *CARBON* factor to determine if carbon emissions are a priced risk factor, we follow the usual Fama-French procedure, using the firms' carbon emission and size. At the end of June each year, we have all stocks independently assigned to one of two size groups, and one of three CF groups. Thus, we form six intersecting size-emission portfolios. To be included in these portfolios, a firm must have a non-negative book-value, trade on the main stock market, NYSE, AMEX, or NASDAQ, not be from a financial industry, and report carbon emissions at the previous year end. As in Fama and French (1993?), size break-points are the medians on the NYSE are value-weighted monthly returns. Portfolios are constructed annually, with July formation dates. As we theorise that higher carbon emission firms have higher systematic risk, the *CARBON* factor is the difference between the (Big/High Emission + Small/High Emission)/2 (HCF) and (Big/Low Emission + Small/Low Emission)/2 portfolios (LCF). Other factors in the Fama-French model are downloaded directly from Ken French's website.

3.3 Factor effectiveness test I: asset pricing tests

For our first test, we follow Fama and Frech (2011), who adopt the asset pricing test method suggested in Gibbons, Ross and Shanken (1989) (GRS). For the test portfolios, we use the value-weighted returns of 25 (5×5) intersecting (independently sorted) size and book-to-market (BTM) portfolios in the asset pricing models from the Ken French's website. The test period is from July 2002 to December 2012.

In running the GRS test, we wish to see whether the addition of the *CARBON* factor has improved the asset pricing model. As described in Cochrane (2001, Ch.12), we regress the individual test portfolio on the Fama-French three factor model and Carhart four factor model. We then add the *CARBON* factor for both models and test whether the alphas are jointly zero. These time-series regressions are as follows:

$$R_{it} - R_{ft} = \alpha_i + \beta_i * F_t + \varepsilon_{it} \qquad (4)$$

R_{it} is the return on a test portfolio i in month t,

R_{ft} is the risk-free rate in month t,

F_t is the vector of factors corresponding to the model that is being tested.

For each of the tested models (with and without the *CARBON* factor), we test whether the intercept terms, α_i, are jointly zero.

3.4 Factor effectiveness test II: Industry portfolio performances

Our next test is based on the 48-industry portfolios, for which the test portfolios are also from the Ken French Website. Again, we use value-weighted portfolios based on the same time period. The list of Fama-French 48-industry and their abbreviation can be found in Appendix. We run the same models as above and report only the exposure to the *CARBON* factor. The test is designed to identify the which industries have more positive exposure to the *CARBON* factor, and examine whether these might logically be expected to be heavy carbon emission industries.

3.5 Long-short portfolios with industry adjustments

Our final test of whether the *CARBON* factor looks like a rationally priced risk factor uses portfolios of firms that are long (positively invested) in low carbon emissions and short (negatively invested) in high carbon emissions. This is, in effect, a zero net investment "arbitrage" portfolio. If the risk pricing model is genuinely capturing a systematic risk exposure we would expect such a portfolio to exhibit a significant negative loading on the *CARBON* factor We first construct test portfolios only with respect to the companies' carbon emission performance, ignoring industry membership. We take the returns on a portfolio of lowest carbon emission, (lowest 30%) minus the returns on a portfolio of the highest carbon emissions (highest 30% emissions), thus forming a long-short carbon ranked portfolio. These are all formed value-weighted and rebalanced yearly. We track the 12-month stock performance after the Trucost carbon information has been released, hence, for the GHG emission data Year 2002 to Year 2012, we have the corresponding stock returns from Year 2003 to Year 2013. We use these long-short portfolio returns as our left hand test variable, and run the above two models with the *CARBON* factor. As explained above, we expect this factor loading to be negative.

Clearly, one would expect there to be substantial industry differences in carbon emissions, and so a natural question is whether the within-industry performance of a firm affects its exposure to this *CARBON* factor. To address this question, we look at two alternative procedures. First, we adopt the Edmans (2011) method, which uses the industry adjusted returns in place of a firm's simple return, which effectively benchmarks the firm's return against the industry return. An alternative way to take account of the industry membership effect is to form ranked portfolios of carbon emissions within each industry. This is a method that has also been used in socially responsible investment papers (e.g. Derwall, Guenster, Bauer, and Koedij, 2005), and is sometimes described as a "best in class" (or industry balanced) portfolio approach.

In this research, we adopt both of these approaches and show both the industry-benchmark and industry-balanced portfolios in our test results.

3.6 Valuation models

Our final tests investigate whether firms with low carbon emissions are valued more highly than firms with higher carbon emissions. Our research model is more sophisticated than a simple Tobin's Q model and empirical variants of this stream research can be traced back to the work of Edwards and Bell (1960), Peasnell (1982) and Ohlson (1995). The model is essentially a variant of the discounted cash flow model that is expressed as a function of accounting earnings, book values and "other information".[6] The Ohlson 1995 model can be simplified into the following linear relationship between firm vale and firm fundamentals:

$$P_t = \beta_1 b_t + \beta_2 x_t + \beta_3 d_t + \beta_4 v_t + \varepsilon_t \quad (5)$$

Where,

x_t = the net income at time t.

[6] See Gregory and Whittaker (2013) for a detailed explanation and an application in the CSR literature.

b_t= the closing book value at time t.

d_t= the dividends at time t.

v_t= non-accounting information, abbreviated for the 'other information', at time t. Expression (5) above is a generalised forms of the model actually estimated, and in our tests we employ the valuation framework in Barth et al. (1998), which allows for industry effects and the evidence that research and development expenditures may be valued by markets (Lev and Sougiannis, 1996). In addition we allow introduction of new capital (Hand and Landsman 2005). In the spirit of this reasrch and following Gregory and Whittaker (2013) method in relation to CSR indicators, we directly test whether carbon emissions are embedded in market prices.

Formally, this involves testing the significance of the coefficient on the CSP parameter in the following pooled regression model:

$$P_{it} = \sum_{j=1}^{j=N} \beta_{0j} IND_{jt} + \beta_1 b_{it} + \beta_2 x_{it} + \beta_3 d_{it} + \beta_4 \Delta C_{it} + \beta_5 RD_{it} + \beta_6 CF_{it} + \varepsilon_{it} \quad (7)$$

Where, in addition to the variables described above:

ΔC_{it} = the net capital contribution, and is equal to the difference between the purchase and sales of common and preferred stocks.

RD_{it} is the research and development expenditure for firm i in year t,

CF_{it} *i*s the carbon footprint measure for firm i in year t,

IND_{jt} is the SIC industry group to which firm i belongs.

Other adjustments include (a) keeping the firms with positive book-values only due to the confusion that may be caused by the negative book-value figures when used as a deflator, (b) following Cohen et al. (2003) in filtering the extreme values, which limit the market-to-book ratio to bigger than 0.01 or less than 100, (c) limiting the market-value-to-sales ratio within the same range.

As one would expect the models' parameters to be very different for loss-making companies, we run the model on a sample which consists of firms with positive earnings only.[7]. One issue in implementing

[7] The Ohlson (1995) model assumes so-called "linear information dynamics", or LID. This makes sense in a world where firms have higher than normal (in the economic sense) earnings that are competed away to a normal level. However, it makes less sense for loss-making firms particularly those that are in a "start up" phase but which markets expect to become profitable, as such firms clearly do not fit the assumed LID.

this sort of model is that of deflation. Following the literature, three different deflators are used to control for scale differences (Barth and Kallapur 1996). These are: common share outstanding, book-value of equity, and sales. The arguments over the most effective deflator remains unsettled to date. While the Trucost data deflate carbon emissions by sales, and this formsour basic definition for the carbon footprint, our choice on the other two deflators is in line with Rees (1997), who employ share numbers, and Rees and Valentincic (2013), who adopt book values. Barth and Clinch (2001 and 2009) both report that the scale effect can be mitigated most effectively by the number of shares in terms of the bias and mean squared error.

All accounting variables are from COMPUSTAT at the end of year t. These include book-value, earnings, dividends, research and development, and net capital contributions. In addition, we also have sales and common share outstanding, for the period of 2002 to 2012. Market value is accessed at June year t+1 from CRSP.

4 Empirical Results

4.1 The *CARBON* factor

In Panel A of Table 1, we report the statistics for all the five factors, calculated over the 126 months period from July 2003 to December 2013. The *CARBON* factor as described in the last section has a mean value of 0.60% per month over the test period.

Panel B of Table 1 reports the correlations between the factors. We find that only the Momentum factor shows a significant positive correlation of 0.30 with the *CARBON* factor. None of the other three factors is significantly correlated with the *CARBON*.

We next turn to our tests that use the *CARBON* factor itself.

4.2 GRS test

Table 2 shows the results of the GRS tests on the 25 SZIE-BTM value-weighted test portfolios. To save space, we do not report the coefficients on the factors for each model. The table has four sets of three-columns, each set representing the results from each of our four models, which are Fama-French three factors model (FF3F), Fama-French three factors plus *CARBON* model (CABN4), Carhart four factors model (FF4F), and Carhart four factors plus *CARBON* model (CABN5).

The first column of each set lists the 25 portfolios name, with the first character denoting size, the second the BTM category. In the second column, we report the α (the intercept) and the third column reports its associated t-statistic.

None of these test results passes the GRS test, which is possibly no surprise given the evidence in Fama and French (2012). However, by comparison, the models that include the *CARBON* factor generally perform better than those without. In the FF3F, 4 of the 25 intercept terms are significant at the 5% level, and 7 are significant at the 1% level. After adding the *CARBON* factor, both of the figures decrease, where now there is 1 significant intercepts at the 5% level and there are 4 at the 1% level. The adjusted R-square has also been improved by 0.19%, and the GRS test p-value has increased to 0.0149. In the FF4F model, there are similar changes in the significance of intercepts and the adjusted R-square. Moreover, the GRS test result has also been improved, where its significance level after including the *CARBON* changes from a 1% level to a 5%.

So far, these results have show that the addition of the *CARBON* factor has improved the model. Further evidence is on its effectiveness provided in the next section.

4.3 Industry Portfolios

Table 3 shows the *CARBON* factor loadings and associated standard errors for each of the 48 industries. Whilst these are essentially intuitive tests, the the industries that one might intuitively expect to be heavy emission industries appear to have a significant positive exposure to the *CARBON* factor.

Unsurprisingly, coal (Coal) has the highest associated emission risk with a coefficient of 1.66 (in the FF4F model 1.68). Subsequently, gold mining (Gold), non-metallic and industrial metal mining (Mines) and petroleum and natural gas (Oil) have coefficients between 0.70 and 0.93.

Notably, agriculture (Agric) and electronic equipment (ElcEq) as also have a positive carbon risk, though the effect is not statistically strong. These two industries have been ignored in most research so far. However, according to the Intergovernmental Panel on Climate Change (IPCC), agriculture is one of the three main causes of the increased greenhouse gases over the past 250 years, the other two being fossil fuels and land use. The reason that the effect is not strong is probably due to the fact that our factor is focusing on carbon emissions, but agriculture is mainly responsible for Methane and Nitrous Oxide GHGs. The likely reason for electronic equipment to be positive is the dioxin emissions produced during the disposal process (Widmer et al., 2005). The problem of waste electrical and electronic equipment (WEEE) has been widely discussed in environmental research, but has not been realised in finance area to date.

Our findings from the industry portfolio results further supports that carbon risk is priced by the market as indicated by the carbon risk factor. Both our econometric and empirical evidence support Hypothesis 1, in which we argue that carbon emission is a priced risk factor.

4.4 Long-short Portfolios

In Table 4 we report the results from analysing the long (low carbon) minus short (high carbon) portfolios. The left hand panel is formed using the industry adjusted benchmark model of Edmans (2011), whilst the right hand panel shows the “best in class” or industry-balanced portfolios.

For the industry benchmark portfolios, we find that the L low-high carbon portfolios show significantly lower market risk. This is a result consistent with the Sharfman and Fernando (2008) finding. However, additionally, we record a significant negative exposure to the *CARBON* factor in both the CABN4 and CABN5model. The FF4F model produces a similar result. We have two observations here, firstly, The fact that an arbitrage portfolio long in low carbon and short in high carbon stocks carries a negative factor loading is consistent with *CARBON* exposure being a priced risk factor.

The industry-balanced portfolios also Provide consistent conclusions with regard to the *CARBON* factor. However, we no longer see significant beta differences but instead see significant positive SMB exposures but negative MOM exposure, which suggests that, within industries, lower carbon firms may be smaller firms but also less exposed to Momentum risk. Interestingly, there is no evidence of a significant intercept in these regressions.

Theoretically, if the *CARBON* factor is a priced risk factor that is captured by the market, then we would not expect to see any significant differences in the intercepts in an efficient market, and the results in Table 4 are broadly supportive of this interpretation.

4.5 Valuation

Our finding that carbon performance may affect a firm's cost of capital, leads us to further investigate whether carbon performance is relevant to firm value. One advantage of the approach we now adopt is that our valuation model is run at the individual firm level, rather than requiring the construction of portfolios, so we can use firm-specific emissions data. We divided the complete sample into profitable firms and loss making ones, This is consistent with the approach in Franzen and Radhakrishnan (2009) who point out that the residual-income type of valuation model is more appropriate for profit firms than loss firms, and the model we employ in this section is derived from the residual-income model.

Our summary statistics and results are presented in Tables 5, 6 and 7. In Table 5, we report the summary statistics for the undeflated values (Panel A) and the values deflated by number of shares, book value and sales respectively (Panels B-D) firms. Table 6 contains the correlations, which we show in three panels for the different deflators. Table 7 presents the results of the valuation models with three panels for different deflators. To show the influence of the carbon variable and the industry effect, we develop our models in three layers; firstly, model 1 is the equation 7 without the carbon term and 48 industry dummies, secondly, model 2 is the equation 7 without the 48 industry dummies, and finally, model 3 is the equation 7.

We first note that the results of the basic model (without carbon) look plausible and in line with those from previous research. As predicted by the basic idea behind the basic Ohlson/residual income model, value is a function of book value and earnings. Further, in line with the enhanced versions of the model in Rees (1997) and Hand and Landsman (2005), dividends, net capital inflows and R&D expenditure Adding the carbon emission variables, which proxy for the carbon emission quantities deflated by different deflators, we see that all three carbon variables are negatively priced, albeit at different confidence intervals. Recall that the carbon emissions are emissions per firm (appropriately scaled) so that these results are telling us that, *ceteris paribus*, the more carbon a firm emits the more its value declines. In the third column we see that this result is robust to the inclusion of industry effects. These results are quite striking, and are clearly robust with respect to the choice of alternative deflators and the inclusion of industry dummies, and provide strong support for our second hypothesis. This outcome is in line with Busch and Hoffmann (2011), who suggest a positive relationship between the firms' outcome based carbon performance and financial performance. Our residual income model does not permit us to explore the non-linear relationship discussed by Misani and Pogutz (2015).

5. Conclusion

Most research to date that has investigated the financial effects of CSP has either investigated a portfolio of stocks or individual firms. In this research, we have conducted comprehensive analysis on firms' carbon emission performance at both the portfolio and firm level. Our first contribution was to show that exposure to a "*CARBON*" factor appears to have the characteristics of a priced systematic risk factor. As a priced systematic risk factor, carbon performance can therefore affect the firms' cost of capital. This result is consistent with the work of Sharfman and Fernando (2008) and El Ghoul et al. (2011), both of whom have provided evidences to support the case that superior environmental-performance/CSP are associated with lower systematic risk. Our second contribution was to show that industry exposures to this factor appear to be consistent with those that one might expect given the nature of each industry. Our third contribution was then to investigate what effect a firm's relative carbon performance might have. We examined this in two ways. First, we looked at the performance of a portfolio of low carbon firms compared to that of a portfolio of high carbon firms. Our results clearly show that low carbon firms do not under-perform but instead show that such firms have lower systematic risk.

Finally, we examined individual firms to establish whether lower carbon emissions contribute to higher stock market valuations. We find that low emissions are indeed associated with higher values, and that this result is robust to the use of alternative deflators and controls for industry effects. Our firm level results support Busch and Hoffmann's (2011) outcome-based measurements result, for a positive CEP–CFP relationship. However, one caveat is that this conclusion is limited to profitable companies, as the theoretical valuation framework we use as the basis for our modelling is not an appropriate one for loss making firms. In particular, it is not appropriate for start-ups and firms in permanent decline.

Taken as a whole our results suggest that low carbon emissions are likely to be associated with a lower cost of capital. However, our valuation results suggest that there may be cash flow effect as well. The cash flow effect could come about either because of higher expected future profits (Gregory, Tharyan and Whittaker, 2014) or greater persistence in abnormal earnings (Gregory, Whittaker and Yan, 2016). However, disentangling these effects is complex and beyond the scope of the current paper.

There are further implications in this paper for investors. Given that lower carbon emissions are associated with a lower cost of capital, or increasing future cash flows, or both, if these effects are known and understood by market participants, they will not appear in the form of excess returns, as carbon performance will be priced by the market. Our results suggest that this is exactly the case. Therefore, investors will neither gain nor lose by investing in firms with low emissions, as carbon risk is in the price. The implications for corporate managers are more inspiring. If carbon emission quantity is negatively priced, a strategy of reducing the emissions either through a simple "end-of-pipe" (e.g. carbon capture) solution or a technological innovation is likely to be value-enhancing.

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Tables

Table 1 US Factors Statistics and Correlation

The table reports the summary statistics (Panel A) and the correlations (Panel B) for the factors used in the paper. RmRf is the market risk premium, SMB, HML and MOM are formed from six intersecting portfolios using market capitalisation and the book-to-market ratio and from intersecting portfolios using size and 12 period past returns, respectively, as described in the text and on Ken French's website. These factors are formed from all NYSE, AMEX, and NASDAQ stocks. *CARBON* is the *CARBON* factor formed from six intersecting portfolios using market capitalisation and the Trucost carbon dioxide emissions descaled by sales, so it is formed from all emissions available NYSE stocks. Statistics reported are the number of time period (N), mean, standard deviation (sd), maximum (max), minimum (min), and median (p50).

Panel A	N	Mean	SD	Median	Min	Max
RMRF	126	0.0071	0.0430	0.0140	-0.1723	0.1134
SMB	126	0.0030	0.0225	0.0007	-0.0422	0.0579
HML	126	0.0019	0.0232	0.0007	-0.0986	0.0759
MOM	126	0.0002	0.0475	0.0030	-0.3472	0.1253
CARBON	126	0.0060	0.0372	0.0043	-0.0810	0.1463

Panel B	RMRF	SMB	HML	MOM	*CARBON*
RMRF	1				
SMB	0.4536	1			
HML	0.3398	0.1535	1		
MOM	-0.3251	-0.0732	-0.3209	1	
CARBON	-0.1533	-0.1035	-0.1427	0.3028	1

Table 2 US 25 SIZE-BM VW Portfolios GRS Tests

The table reports the results of the first-stage regression tests of the value-weighted returns of 25 (5×5) intersecting (independently sorted) size and book-to-market (BTM) portfolios on the asset pricing models as specified in the text. Test portfolios are from Fama-French Website. These are using all NYSE, AMEX, and NASDAQ stocks. The first character denotes size, the second the BTM category, so for example SL denotes small – low BTM, S2 denotes size and second lowest BTM category, whilst B4 denotes big and fourth highest BTM category, and BH denotes big and high BTM. However, outside the smallest and largest categories, we use three characters, so that, for example, M34 denotes the middle (third) size portfolio and the fourth largest book-to-market portfolio. Specifically for the GRS test of Gibbons, Ross and Shanken (1989), we run time series regression of the form $R_{it} - R_{ft} = \alpha_i + \beta_i F_t + \varepsilon_{it}$ where R_{it} is the return on a test portfolio in month t, R_{ft} is the risk-free rate in month t, F_t is the vector of factors corresponding to the model that is being tested. The regression on each of the test portfolio yields an $\hat{\alpha}_i$ (the intercept), and we test for the rejection of the null hypothesis that all the intercept terms are jointly zero using the GRS test. For each of models, the table reports the α (the intercept) and its associated t-statistic for the individual portfolios. GRS is the GRS test statistic, p-val. is its p-value, mean R2 is the mean adjusted R-squared from the regressions, meancon is the mean α, meanabscon is the mean absolute α, meanse is the mean standard error of the α, p <= 0.05 is the number of intercept terms that are significant at the 5% level, and p <= 0.1 is the number of intercept terms that are significant at the 10% level. ***, ** and * represent the significance at 1%, 5% and

FF3F			CABN4			FF4F			CABN5		
SL	-.0062375***	-3.7392000	SL	-.006342***	-3.71902	SL	-.0059647***	-3.6525900	SL	-.0062776***	-3.78331
S2	-0.0010765	-0.9129850	S2	-.0008511	-.70864	S2	-0.0010123	-0.8557710	S2	-.0008409	-.69825
S3	-0.0010808	-1.0654200	S3	-.0005349	-.532803	S3	-0.0009738	-0.9648150	S3	-.0005213	-.519063
S4	-0.0009936	-0.9042760	S4	-.0003586	-.331467	S4	-0.0010504	-0.9526790	S4	-.0003841	-.357864
SH	0.0011785	0.9279050	SH	.0018434	1.46386	SH	0.0012325	0.9662000	SH	.0018426	1.45704
M2L	0.0002444	0.2079010	M2L	.0001857	.154534	M2L	0.0003041	0.2577850	M2L	.0002005	.166687
M22	0.0007743	0.8168650	M22	.000528	.548717	M22	0.0008133	0.8541590	M22	.0005418	.563124
M23	.0018563*	1.8508100	M23	.001429	1.42177	M23	.0018464*	1.8297900	M23	.0014352	1.42302
M24	-0.0005884	-0.5376430	M24	-.0006248	-.558304	M24	-0.0006528	-0.5948980	M24	-.0006388	-.57031
M2H	-0.0003402	-0.2627580	M2H	8.91e-06	.0067845	M2H	-0.0003562	-0.2734690	M2H	-1.64e-06	-.001244
M3L	0.0000432	0.0372483	M3L	-1.82e-06	-.0015294	M3L	0.0001472	0.1270780	M3L	.0000228	.0193315
M32	.0022966**	2.1136000	M32	.0019024*	1.73719	M32	.0023793**	2.1889800	M32	.0019291*	1.77689
M33	.0023793*	1.8679100	M33	.001507	1.22139	M33	.0023122*	1.8090800	M33	.0015089	1.2178
M34	0.0016856	1.2049000	M34	.000779	.57144	M34	0.0014883	1.0790000	M34	.0007518	.553925
M3H	.003502**	2.2229200	M3H	.0027224*	1.73702	M3H	.0033171**	2.1220200	M3H	.0026956*	1.7235
M4L	.0021608**	1.9941400	M4L	.0019651*	1.77962	M4L	.0021615**	1.9824900	M4L	.0019691*	1.7762
M42	0.0005843	0.5085850	M42	.0000757	.0658535	M42	0.0006422	0.5569350	M42	.000099	.0864929
M43	-0.0013252	-0.9007000	M43	-.0015703	-1.04674	M43	-0.0011856	-0.8081640	M43	-.0015335	-1.03129
M44	0.0012098	0.7983300	M44	.0001141	.0782329	M44	0.0010794	0.7131770	M44	.0001059	.0723811
M4H	-0.0002316	-0.1586990	M4H	-.0000242	-.0162302	M4H	0.0000192	0.0134988	M4H	.000029	.0199659
BL	0.0005186	0.7078330	BL	.0007675	1.03757	BL	0.0006104	0.8413650	BL	.0007835	1.06563
B2	0.0016028	1.6446800	B2	.0014431	1.45214	B2	0.0013937	1.4915600	B2	.0013985	1.46618
B3	-0.0011184	-0.9685900	B3	-.0006849	-.589148	B3	-0.0010585	-0.9135550	B3	-.0006798	-.582512
B4	-.0017442*	-1.7439400	B4	-.0014849	-1.46255	B4	-.0017298*	-1.7192700	B4	-.0014867	-1.45825
BH	0.0002698	0.1347910	BH	-.000573	-.28558	BH	0.0003813	0.1899550	BH	-.0005309	-.265994
GRS	2.0589		GRS	1.8867		GRS	2.0190		GRS	1.8780	
p-val	0.0065***		p-val	0.0149**		p-val	0.0080***		p-val	0.0157**	
meanR2	0.9363		meanR2	0.9382		meanR2	0.9371		meanR2	0.9388	
meancon	0.0002		meancon	0.0001		meancon	0.0002		meancon	0.0001	
meanabscon	0.0014		meanabscon	0.0011		meanabscon	0.0014		meanabscon	0.0011	
meanse	0.0012		meanse	0.0012		meanse	0.0012		meanse	0.0012	
p<=.05	4		p<.05	1		p<=.05	4		p<.05	1	
p<=0.1	7		p<.01	4		p<=0.1	7		p<.01	4	

10% significance levels respectively.

Table 3 US *CARBON* Factor Loadings for 48 Industries

The table reports the *CARBON* factor loadings in each of the regressions for 48 industry portfolios, value-weighted portfolios. Models adopted are Fama-French three factors and Carhart four factors, respectively. *RmRf* is the market risk premium, *SMB*, *HML* and *MOM* are formed from six intersecting portfolios using market capitalisation and the book-to-market ratio and from intersecting portfolios using size and 12 period past returns, respectively, as described in the text and on Ken French's website. These factors are formed from all NYSE, AMEX, and NASDAQ stocks. However, we do not report these factors here. *CARBON* is the *CARBON* factor formed from six intersecting portfolios using market capitalisation and the Trucost carbon dioxide emissions descaled by sales, and it is formed from all emissions available NYSE, AMEX, and NASDAQ stocks. *se* is standard errors, and ***, ** and * represent the significance at 1%, 5% and 10% significance levels respectively.

IND	**CABN4**	**CABN5**	IND	**CABN4**	**CABN5**	IND	**CABN4**	**CABN5**
Agric	0.3051**	0.2695*	BldMt	0.0759	0.1563*	PerSv	-0.1521	-0.2249*
	(0.1395)	(0.1446)		(0.0859)	(0.0848)		(0.1147)	(0.1166)
Food	-0.0320	-0.0260	**Cnstr**	**0.2685*****	**0.2601****	BusSv	-0.0198	-0.0183
	(0.0599)	(0.0623)		**(0.1000)**	**(0.1039)**		(0.0442)	(0.0460)
Soda	-0.1731	-0.0784	**Steel**	**0.5048*****	**0.5124*****	Comps	-0.0803	-0.0699
	(0.1227)	(0.1232)		**(0.1119)**	**(0.1164)**		(0.0762)	(0.0792)
Beer	-0.0094	-0.0443	**FabPr**	**0.2848****	**0.3353*****	Chips	-0.0565	-0.0574
	(0.0682)	(0.0698)		**(0.1161)**	**(0.1195)**		(0.0697)	(0.0725)
Smoke	0.0599	0.0293	**Mach**	**0.3378*****	**0.3604*****	LabEq	0.0781	0.0510
	(0.1077)	(0.1115)		**(0.0700)**	**(0.0724)**		(0.0651)	(0.0670)
Toys	-0.0811	-0.0263	ElcEq	0.1472**	0.1643**	Paper	-0.0620	-0.0123
	(0.0949)	(0.0969)		(0.0727)	(0.0753)		(0.0695)	(0.0701)
Fun	-0.1792	-0.0328	Autos	0.0054	0.1849	Boxes	0.0528	0.0815
	(0.1147)	(0.1077)		(0.1270)	(0.1162)		(0.0766)	(0.0791)
Books	-0.1950**	-0.1106	Aero	-0.0224	0.0126	Trans	-0.0589	-0.0614
	(0.0866)	(0.0851)		(0.0742)	(0.0762)		(0.0692)	(0.0720)
Hshld	-0.0601	-0.0588	**Ships**	**0.2909*****	**0.3315*****	Whlsl	0.0642	0.1050**
	(0.0640)	(0.0666)		**(0.1110)**	**(0.1146)**		(0.0464)	(0.0461)
Clths	-0.2271***	-0.1703*	Guns	-0.0460	0.0039	**Rtail**	**-0.2779*****	**-0.2867*****
	(0.0865)	(0.0878)		(0.1068)	(0.1097)		**(0.0583)**	**(0.0606)**
Hlth	-0.1142	-0.0842	**Gold**	**0.9018*****	**0.9335*****	Meals	-0.1572**	-0.1580**
	(0.0809)	(0.0835)		**(0.2252)**	**(0.2340)**		(0.0625)	(0.0650)
MedEq	-0.0122	0.0054	**Mines**	**0.7275*****	**0.6989*****	**Banks**	**-0.4885*****	**-0.4291*****
	(0.0733)	(0.0760)		**(0.1555)**	**(0.1614)**		**(0.0666)**	**(0.0661)**
Drugs	-0.0203	-0.0288	**Coal**	**1.6568*****	**1.6802*****	**Insur**	**-0.1879*****	**-0.1525****
	(0.0661)	(0.0687)		**(0.2126)**	**(0.2210)**		**(0.0608)**	**(0.0620)**
Chems	**0.1575****	**0.1992*****	**Oil**	**0.7729*****	**0.7194*****	RlEst	-0.0784	0.1045
	(0.0729)	**(0.0744)**		**(0.0799)**	**(0.0810)**		(0.1334)	(0.1232)
Rubbr	-0.0551	0.0211	**Util**	**0.2796*****	**0.2315*****	Fin	-0.1322*	-0.1027
	(0.0792)	(0.0779)		**(0.0638)**	**(0.0642)**		(0.0744)	(0.0767)
Txtls	-0.3948***	-0.2158	Telcm	0.0214	0.0086	**Other**	**-0.2384*****	**-0.1996****
	(0.1488)	(0.1416)		(0.0525)	(0.0544)		**(0.0769)**	**(0.0789)**

Table 4 US Long Short Portfolios

The table reports the alphas and *CARBON* betas in each of the portfolios formed by the carbon emission criterion at 30% cut-off level, value-weighted (VW). Model adopted is Fama-French three factors (FF3F) and four factors (FF4F). The portfolios presented on the left are formed after taking out each industry benchmark returns, value-weighted, and then selected at 30% cut-off levels ignoring the industry difference, i.e. pooled-industries. The portfolios presented on the right are formed after balancing the industries, i.e. using the selected companies from each industry at 30% cut-off levels, value-weighted, then taking out the risk-free returns. *RmRf* is the market risk premium. *CARBON* is the *CARBON* factor formed from six intersecting portfolios using market capitalisation and the Trucost carbon dioxide emissions descaled by sales. *SMB*, *HML* and *MOM* are formed from six intersecting portfolios using market capitalisation and the book-to-market ratio and from intersecting portfolios using size and 12 period past returns, respectively, as described in the text and on Ken French's website. These factors are formed from all NYSE, AMEX, and NASDAQ stocks. Carbon emission criterion is the Trucost carbon dioxide emissions (refers to CO2 only, not include the equivalent of other greenhouse gases) divided by the companies' sales. The 48 industry classification follows Standard Industrial Classification (SIC). These are four digit numerical codes assigned by the U.S. government to business establishments to identify the primary business of the establishment. The Definitions of each of the 48 categories and the benchmark returns (value-weighted) are all from Fama-French Website. http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/det_48_ind_port.html. Standard errors are shown in parentheses and significance levels are indicated by * for 10%, ** for 5% and *** for 1%.

	Industry Benchmark				**Industry Balanced**			
	FF3F	**CABN4**	**FF4F**	**CABN5**	**FF3F**	**CABN4**	**FF4F**	**CABN5**
RMRF	**-0.0599*** **	**-0.0670*** **	**-0.0676*** **	**-0.0689*** **	0.1095	0.0621	0.0317	0.0234
	0.0184	**0.0169**	**0.0189**	**0.0175**	0.0686	0.047	0.0657	0.0465
SMB	-0.0039	-0.0098	0.0008	-0.0083	0.2230*	0.1839**	0.2714**	0.2131**
	0.0334	0.0306	0.0333	0.0309	0.1245	0.0851	0.1157	0.082
HML	0.0135	0	0.0018	-0.0028	0.141	0.0503	0.0217	-0.0077
	0.0306	0.0282	0.0313	0.029	0.1143	0.0784	0.1089	0.0771
CARBON		**-0.0824*** **		**-0.0804*** **		**-0.5531*** **		**-0.5118*** **
		0.0168		**0.0175**		**0.0467**		**0.0463**
MOM			-0.0242	-0.0065			-0.2454***	-0.1332***
			0.0153	0.0147			0.0532	0.039
_cons	0.0006	0.0012*	0.0006	0.0012*	-0.0043*	-0.0003	-0.0036	-0.0003
	0.0007	0.0006	0.0007	0.0006	0.0025	0.0018	0.0023	0.0017
adj. R-sq	0.0823	0.2284	0.0934	0.2233	0.0892	0.575	0.2191	0.6095
N	126	126	126	126	126	126	126	126
F	4.74	10.25	4.22	8.19	5.08	43.29	9.77	40.02

Table 5 Profitable Company Summary Statistics

Table contains only profit companies, i.e. positive earnings and positive book-value in year t. MV, the market value, BV, book-value, NI, earnings, DIV, dividends, RD, research and development, Netcap, net capital contributions, equals to the purchase of common and preferred stock – sales of common and preferred stock, Totalturnover, Sales, csho, common stock share number, for the period of 2002 to 2012, market value is at June year t+1, all else accounting variables are at end of year t.

Panel A	N	mean	p50	min	max	sd	skewness	kurtosis
MV	6931	15130.61	5182.14	49.497	547363.4	31982.89	6.031536	55.75344
BV	6931	6432.076	2146.599	4.170188	218187.6	14310.45	6.518034	60.85453
NI	6931	1002.219	303.5919	0	43689.28	2456.079	7.779524	93.43499
DIV	6928	319.8649	59.4951	0	35557.2	983.8091	11.26619	274.1928
RD	6931	240.2067	0	0	12183	895.2802	6.603618	54.18087
Netcap	6407	313.3136	26.591	-44869	34981	1653.724	1.460966	218.7628
Totalturnover	6931	11713.07	4021.52	47.01	467029	27400.59	8.076698	97.89335
csho	6931	419.6155	158.306	0.001	29058.36	939.7318	8.644203	157.7659

Table contains only profit companies, i.e. positive earnings and positive book-value in year t. MVps, the market value per share, BVps, book-value per share, Eps, earnings per share, DIVps, dividend per share, RDps, research and development per share, Netcapps, net capital contributions per share, CFps, carbon emissions per share. For the period of 2002 to 2012, market value is at June year t+1, all else accounting variables and carbon variable are at end of year t.

Panel B	N	mean	p50	min	max	sd	skewness	kurtosis
MVps	6931	45.40443	38.16	2.07	810	39.88958	7.113497	87.65868
BVps	6931	107.3159	14.4552	0.0532	346442	5234.774	60.3823	3704.135
Eps	6931	2.745234	2.08	0	110.36	3.503009	13.10252	307.9448
DIVps	6928	0.698313	0.425833	0	30.81	1.067334	9.508896	203.6738
RDps	6931	91.54469	0	0	384806	5488.978	62.74628	4069.087
Netcapps	6407	0.786582	0.182756	-42.4078	168.7726	3.943049	19.21249	697.7413
CFps	6931	16574.25	398.0561	0	1.86E+07	280870.8	53.36191	3188.112

Table 5 Profitable Company Summary Statistics (cont.)

Table contains only profit companies, i.e. positive earnings and positive book-value in year t. PBV, the market value per book-value, OBV, one over book-value, NBV, earnings per book-value, DBV, dividend per book-value, RBV, research and development per book-value, NCBV, net capital contributions per book-value, CFBV, carbon emissions per book value. For the period of 2002 to 2012, market value is at June year t+1, all else accounting variables and carbon variable are at end of year t.

Panel C	N	mean	p50	min	max	sd	skewness	kurtosis	
PBV	6931	3.348998	2.412984	0.036245	94.59778	4.337206	9.460026	140.3877	
OBV	6931	0.000823	0.000466	4.58E-06	0.239797	0.003283	56.98879	4062.537	
NBV	6931	0.186334	0.145272	0	6.141395	0.237778	9.949299	158.0426	
DBV	6928	0.056363	0.026444	0	29.97602	0.385197	68.53613	5265.488	
RBV	6931	0.046883	0	0	5.195448	0.148657	17.38311	477.0287	
NCBV	6407	0.071685	0.012647	-4.24247	11.11847	0.330253	14.51076	396.1808	
CFBV	6931	863.3824	34.08039	0	853939.7	14631.01	54.98062	3152.033	

Table contains only profit companies, i.e. positive earnings and positive book-value in year t. PSA, the market value per sales, BVSA, book-value per sales, NSA, earnings per sales, DSA, dividends per sales, RSA, research and development per sales, NCSA, net capital contributions per sales, CFSA, carbon emissions per share. For the period of 2002 to 2012, market value is at June year t+1, all else accounting variables and carbon variable are at end of year t.

Panel D	N	mean	p50	min	max	sd	skewness	kurtosis
PSA	6931	2.265162	1.513969	0.015811	41.53191	2.331109	3.314288	26.99409
BVSA	6931	0.891655	0.619163	0.00261	20.82309	0.942753	4.435413	48.14919
NSA	6931	0.117284	0.088497	0	2.367491	0.109241	4.357271	49.90955
DSA	6928	0.040871	0.013929	0	2.65393	0.098	8.673502	144.4419
RSA	6931	0.029634	0	0	0.484792	0.062153	2.80941	11.72871
NCSA	6407	0.016304	0.007042	-6.41543	5.82641	0.230079	-9.66339	349.6836
CFSA	6931	445.2102	16.41893	0	538064.8	7828.117	60.00763	3807.699

Table 6 Profitable Company Correlations

Panel A	MVps	BVps	Eps	DIVps	RDps	Netcapps	CFps
MVps	1						
BVps	0.6817	1					
Eps	0.7585	0.624	1				
DIVps	0.1595	0.1696	0.1346	1			
RDps	0.0754	-0.0599	0.0262	-0.0465	1		
Netcapps	0.4421	0.1893	0.5336	-0.0392	0.0426	1	
CFps	-0.0118	0.0107	0.0053	0.0184	-0.0248	-0.0085	1

Panel B	PBV	OBV	NBV	DBV	RBV	NCBV	CFBV
PBV	1						
OBV	0.3419	1					
NBV	0.8324	0.2413	1				
DBV	0.2286	0.0903	0.2162	1			
RBV	0.2752	0.0921	0.2791	0.0121	1		
NCBV	0.5783	0.158	0.5943	0.0192	0.1479	1	
CFBV	0.0012	0.0712	0.0065	0.0008	0.0127	-0.0107	1

Panel C	PSA	BVSA	NSA	DSA	RSA	NCSA	CFSA
PSA	1						
BVSA	0.6569	1					
NSA	0.6139	0.5924	1				
DSA	0.3635	0.4738	0.4291	1			
RSA	0.3502	0.1159	0.1794	-0.0628	1		
NCSA	-0.1111	-0.3237	-0.0877	-0.2831	0.1102	1	
CFSA	-0.0276	-0.0105	-0.0176	-0.0028	-0.0253	-5.40E-03	1

The original variables before deflation show in Panel A, then for the three different deflators we adopted, Panel B is used to show the variables deflated by share numbers, Panel C the variables deflated by closing book-values, and Panel D the variables deflated by sales.

Table 7 US Profitable Companies' Valuation Results

The Table shows the results of regressing market value on accounting values and carbon variable, contains only profit companies, i.e. positive earnings and positive book-value in year t. MV denotes market value, BV book value, NI net income, Div dividends, NetCap net capital contributions, RD research and development expenditure (assumed to be zero for firms where RD is not reported), CF is the carbon emission quantity from Trucost data, and IND is the 48 industry dummies. Three sets of regressions are shown, with the first deflating by number of shares, the second deflating by book-value, and the third set deflated by sales. All three models deflated by book-value run with intercept (BV/BV). The models deflated by either share number or sales run without intercept before including the industry dummies, with intercept after including the industry dummies (but none of these intercept are reported here). Two-way clustered standard errors are shown in parentheses and significance levels are indicated by * for 10%, ** for 5% and *** for 1%.

Panel A	**Model 1**	**Model 2**	**Model 3**	**Panel B**	**Model 1**	**Model 2**	**Model 3**	**Panel C**	**Model 1**	**Model 2**	**Model 3**
1/ps	459.5030***	459.7655***	2254.6717**	**1/BV**	180.1492***	181.3451***	2033.2891*	**1/sales**	654.1263***	654.1206***	2671.5461
	150.2206	150.2039	1067.06		49.0803	49.1068	1187.3999		117.7772	117.7597	10644776.55
BV/ps	0.6682***	0.6684***	0.5875***	**BV/BV**	0.6717***	0.6740***	0.6062***	**BV/sales**	0.9653***	0.9657***	0.9146***
	0.1544	0.1544	0.1313		0.2175	0.2175	0.1537		0.1177	0.1177	0.0942
NI/ps	5.4001***	5.4016***	4.8772***	**NI/BV**	12.1868***	12.1873***	10.3380***	**NI/sales**	5.7650***	5.7669***	5.0996***
	1.4759	1.4763	1.4500		1.4393	1.4399	1.0680		0.9846	0.9849	0.9543
DIV/ps	4.9586***	4.9676***	1.7213***	**DIV/BV**	0.6706***	0.6698***	0.8193***	**DIV/sales**	1.4917**	1.4913**	1.7173***
	1.4469	1.4489	0.6269		0.1542	0.1539	0.1238		0.6567	0.6569	0.5629
RD/ps	7.9061***	7.9015***	4.6516***	**RD/BV**	1.5326	1.5362	4.3725***	**RD/sales**	8.1457***	8.1415***	7.6739***
	1.0786	1.0788	0.9832		1.3070	1.2999	1.4514		1.4069	1.4069	1.3431
NetCap	1.0052***	1.0038***	1.0453***	**NetCap/BV**	1.7653***	1.7612***	1.9257***	**NetCap/sales**	0.6471*	0.6475*	0.5398
	0.2970	0.2971	0.3738		0.5505	0.5511	0.3181		0.3482	0.3484	0.3681
CF/ps		**-0. 0013*** **	**-0. 0015*** *	**CF/BV**		**-0. 0036*** *	**-0. 0017*** **	**CF/sales**		**-0. 0023*** *	**-0.0025*** *
		0. 0005	**0. 0006**			**0. 0017**	**0. 0004**			**0.0009**	**0.0012**
IND/ps	N	N	Y	**IND/BV**	N	N	Y	**IND/sales**	N	N	Y
N	6404	6404	6404	**N**	6404	6404	6404	**N**	6404	6404	6404
adj.Rsq	0.834	0.834	0.696	**adj.Rsq**	0.730	0.730	0.800	**adj.Rsq**	0.802	0.802	0.645
r2	0.83	0.83	0.70	**r2**	0.73	0.73	0.80	**r2**	0.80	0.80	0.65
F	849.49	764.20	28.63	**F**	65.72	56.19	2177.16	**F**	796.73	696.51	73.44

Appendix US 48 Industry Abbreviations

SIC 48 INDUSTRY	Abbreviation
Aircraft	Aero
Agriculture	Agric
Automobiles and Trucks	Autos
Banking	Banks
Beer & Liquor	Beer
Construction Materials	BldMt
Printing and Publishing	Books
Shipping Containers	Boxes
Business Services	BusSv
Chemicals	Chems
Electronic Equipment	Chips
Apparel	Clths
Construction	Cnstr
Coal	Coal
Computers	Comps
Pharmaceutical Products	Drugs
Electrical Equipment	ElcEq
Fabricated Products	FabPr
Trading	Fin
Food Products	Food
Entertainment	Fun
Precious Metals	Gold
Defence	Guns
Healthcare	Hlth
Consumer Goods	Hshld
Insurance	Insur
Measuring and Control Equipment	LabEq
Machinery	Mach
Restaurants, Hotels, Motels	Meals
Medical Equipment	MedEq
Non-Metallic and Industrial Metal Mining	Mines
Petroleum and Natural Gas	Oil
Almost Nothing	Other
Business Supplies	Paper
Personal Services	PerSv
Real Estate	RlEst
Retail	Rtail
Rubber and Plastic Products	Rubbr
Shipbuilding, Railroad Equipment	Ships
Tobacco Products	Smoke
Candy & Soda	Soda
Steel Works Etc	Steel
Communication	Telcm
Recreation	Toys
Transportation	Trans
Textiles	Txtls
Utilities	Util
Wholesale	Whlsl

The industry classification follows Standard Industrial Classification (SIC). These are four digit numerical codes assigned by the U.S. government to business establishments to identify the primary business of the establishment. The Definitions of each of the 48 categories are the same as Fama-French Website.