The Value Relevance of a Firm's Carbon Profile

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Abstract

This study revisits the valuation relevance of a firm's carbon profile using a broader notion of a firm's carbon profile, which includes carbon risk exposure, aside from emissions, and proactive carbon responses (PCRs), identified from publically available information. Initially, we use extant literature and interviews with 28 managers of high carbon emitting firms and five ESG analysts to inform the operationalisation of carbon-risk exposure and identification of PCRs from publically available data. From this, we test the valuation effects of our broader notion of a firm's carbon profile using a modified Ohlson valuation model and a sample of 51 firms (122 firm-year observations) reporting under the NGER scheme with the necessary financial and market data. We document that, on average, a one standard deviation change in the level of the expanded carbon-risk exposure results in a penalty of 12% of market capitalisation of the sample firms on average. We also find that PCRs partially mitigate the documented penalty on high emitters. The interview results suggest that in terms of PCRs, managers and analysts perceive value in firms developing intangible carbon-related capabilities around adaptability, carbon leadership and stakeholder trust. Our empirical results are consistent with this proposition since we find that adaptability, carbon leadership and stakeholder trust partially mitigate the emissions penalty, whereas emissions reductions do not. Taken together these results are consistent with the argument that capital markets impound the valuation impacts of other carbon-risk exposure, aside from emissions, and PCRs identified from publically available information in firm valuations.

Key words: Value relevance, carbon risk, carbon profile, carbon mitigation, carbon risk exposure, proactive carbon response

The Value Relevance of a Firm's Carbon Profile

1 Introduction

The objective of this study is to revisit the valuation relevance of a firm's carbon risk exposure using a broader notion of a firm's carbon profile. For the purposes of this study, we view a firm's carbon profile as comprising both carbon risk exposure and carbon risk mitigation. We define carbon risk exposure as the possibility of future adverse effects on the firm's operations, reputation and financial performance arising from the production and/or application of carbon emitting inputs and processes in its daily activities;[1] and carbon risk mitigation as actions and/or decisions that demonstrate the anticipatory or pre-meditated positioning of the firm to enable timely responses to future carbon risks.

In the main, the extant literature uses a firm's historical carbon emissions data in tonnes as a proxy for carbon risk exposure, largely for practical reasons. However, as pointed out by Clarkson, Li, Pinnuck, and Richardson (2015), the reliance on emissions alone suffers from a series of limitations. The first limitation is the historical orientation of emissions data. Specifically, capital market participants are interested in information about the *future* carbon performance of firms, while prior studies such as Matsumura, Prakash, and Vera-Muñoz (2014) and Griffin, Lont, and Sun (2017) rely on using *historic* carbon emissions data which do not necessarily reflect the firms' future carbon footprint. There is therefore potentially a 'disconnect' between the firms' past carbon footprint as revealed by firms and its future carbon footprint that is of interest to investors and analysts. Secondly, the tonnage of carbon emissions represents only a part of the firm's exposure. Notably, carbon risks also exist because of the

[1] We restrict our analysis in this paper to carbon risks rather than broader climate change risks. This decision was made based on the specific industries selected for this study, which may be less concerned with the physical effects of climate change (Foerster, Peel, Osofsky, & McDonnell, 2017) such as rising sea levels and changing temperatures. Interview participants, who indicated that their greatest threats came from regulatory uncertainty, stakeholder pressure and changing technology rather than the physical effects of climate change, confirmed the validity of this design decision.

possibility of fossil fuels assets becoming stranded (Carbon Tracker Initiative, 2013a; Linnenluecke, Meath, Rekker, Sidhu, & Smith, 2015) and relatedly due to reputational risks (Kytle & Ruggie, 2005). Thirdly, the reliance on emissions ignores how firms respond to and manage carbon risks, which has implications for the future carbon performance and carbon risk exposure of the firm. On this point, Clarkson et al. (2015) already provide some evidence that markets do not assess carbon liabilities uniformly. Rather, they find that investors incorporate information into their valuation decisions about the firm's ability to pass on carbon costs and the extent to which carbon liabilities are covered by allowances in forming their valuation decisions.

To confront these limitations, we develop a broader measure in the form of a firm's carbon profile to capture *future* potential carbon performance. We operationalise this measure by drawing from the extant literature and exploring the identified themes in interviews with 28 managers from seven ASX-listed, high carbon emitting firms in their role as financial statement preparers, and five Environmental, Social and Governance (ESG) analysts in their role as statement users. Our aim is to develop a proxy for a firm's carbon profile from publicly disclosed data.

The firm's carbon profile encompasses both a broader concept of carbon risk as well as carbon mitigation capabilities. In terms of a broader measure of carbon risk which we label 'other carbon risk', prior literature (Carbon Tracker Initiative, 2013b; Hoffmann & Busch, 2008; Linnenluecke, Birt, Lyon, & Sidhu, 2015) and the manager and analyst interviewees highlight the importance of business risk arising from a firm's dependency on fossil fuels, as well as reputational risk arising from a firm's visibility in the carbon arena. Dependency on fossil fuels exposes firms to risk because of their natural scarcity, as well as socio-political factors such as government policies and changes in consumer preferences which at the extreme may leave stranded assets.[2] In addition, being visible in relation to carbon contributes to risk around brand image if a firm is branded as irresponsible (Kytle & Ruggie, 2005). In turn, this reputational damage may affect future operations, competitive market position and ultimately cash flows (Labatt and White, 2007). Thus, on balance we expect that our proxy for other carbon risk will have a negative valuation penalty that is incremental to the traditional proxy for carbon risk, historical carbon emissions measured in tonnes.

We operationalise our four-item ‘other carbon risk’ proxy using hand-collected data from publicly available sources including annual reports, corporate websites, ASSET4 ESG and Factiva. The other carbon risk measure comprises four items relating to the subcomponent of dependency (carbon intensity of the firm’s products and the firm’s supply chain position) and the subcomponent of visibility (the extent of analyst following and negative press coverage of carbon-related issues).

The second aspect of a firm’s carbon profile highlighted in prior literature and by the manager and analyst interviewees is the firm’s managerial response to its carbon risk exposure. We label this response as a ‘proactive carbon response’. Differential carbon valuation penalties (e.g.AMP Capital, 2016; Clarkson et al., 2015; Deutsche Bank, 2009; IRRCi & Trucost, 2009), and the raft of studies within the business strategy literature identifying a variety of environmental/climate change strategies and responses (e.g.Aragon-Correa & Sharma, 2003; Jeswani, Wehrmeyer, & Mulugetta, 2008; Lee, 2012), suggest that firms have differential capabilities for managing their carbon risk exposure. Progressing this argument through the lens of Hart’s (1995) natural resource-based view of the firm, we argue that valuable, costly-to-copy firm resources and capabilities combine to provide the firm with the capacity to

[2] Stranded assets are assets which are ‘considered uneconomical or cannot be developed or extracted as a result of technological, geographical, regulatory, political or market limitations, or changes in social and environmental norms’ (Bos & Gupta, 2018: 436) . To illustrate this risk, McGlade and Ekins (2014) estimate that only 20% of global fossil fuel reserves could be extracted.

respond to future carbon risk on a timely basis. In this sense, the unique, firm-specific combination of resources and capabilities facilitates decisions and actions that are anticipatory of future developments. Thus, they may convey a competitive advantage which is likely valuation relevant. To illustrate, if a firm has the resources and capability to reduce its reliance on fossil fuels through increased use of alternate energy and fuels, it is creating future adaptive capacity to potential carbon risks (Busch, 2011). On balance, we expect that a firm's proactive carbon response will at least partly mitigate the carbon risk valuation penalty.

We operationalise our 57-item proactive carbon response (PCR) index using hand-collected data from publically available data sources including firms' annual reports, sustainability reports (or equivalent), corporate websites, the NGER database, CDP responses, NGO websites, LinkedIn, Factiva, Dow Jones Sustainability Index, FTSE4GOOD index, UN Global Compact list of signatories, We Mean Business coalition website, and relevant government databases[3] that reveal the involvement of firms in offsetting activities. The PCR index comprises five dimensions which include: a demonstrated awareness of carbon risks and issues (14 indicators); carbon leadership in pursuing carbon management activities (10 indicators); demonstrated adaptability to uncertainty in relation to regulation, stakeholder demand and technological developments (13 indicators); responses undertaken to develop and maintain stakeholder trust (17 indicators); and linking beneficial outcomes to carbon responses (3 indicators). In deriving the PCR index, we drew from the extant literature on carbon/climate change strategies, the responses of the manager and analyst interviewees, and established carbon-related frameworks including the Global Reporting Initiative G4 guidelines (2015), the International <IR> Framework (2013) and the Carbon Disclosure Project (2015).

[3] These include the Australian Government's Emissions Reduction Fund (ERF) database, New South Wales Energy Saving Scheme (ESS) database, and Victoria Energy Efficiency Target (VEET) database.

To investigate the valuation relevance of a firm's carbon profile, we use a modified Ohlson valuation model consistent with Collins, Maydew, and Weiss (1997), which relates the market value of the firm to the book value of its equity and earnings. We include not only the firm's historical carbon emissions in tonnes in the model, but also the proxies for other carbon risk and proactive carbon responses. Our final sample comprises 122 firm-year observations (51 firms) drawn from the high carbon emitting sectors of Energy, Materials, Industrials and Utilities that are listed on the ASX with the necessary financial and market data in the Thomson Reuters Datastream database, as well as carbon emissions data from the National Greenhouse Energy Reporting (NGER) database over the period 2014 to 2016. The sample period begins in 2014 when the current regulation, the *Direct Action Plan*, came into effect.

We find evidence that suggests a firm's carbon profile is valuation relevant. In terms of other carbon risk, we document that firms with higher exposure to carbon risk suffer a valuation penalty that is economically significant when compared to less exposed firms. Specifically, a one standard deviation change in the level of other carbon risk exposure maps into a penalty of $1.3 billion. In terms of proactive carbon responses, we find that the valuation penalty assigned to high carbon emitting firms based on their historical carbon emissions is partially mitigated for firms with more proactive carbon responses relating to the dimensions of adaptability, carbon leadership and stakeholder trust. However, these proactive carbon responses do not appear to mitigate the penalty assigned to firms with high exposure to other carbon risk. Interestingly, we also document that achieved emissions reductions are not perceived by investors to mitigate the valuation penalty imposed on high emitters, suggesting that emissions reductions have limited usefulness in assessing the *future* carbon performance of firms. This may be because there is very little scope for firms that have already attained a high level of efficient emissions management to achieve further substantive emissions reductions.

This study extends the current literature in several ways. First, it examines the value relevance of a firm's carbon profile by moving away from the reliance on historic emissions as a measure of such carbon profile, through the operationalisation of a more comprehensive measure of a firm's carbon profile. This is consistent with industry observations that historical emissions may not adequately reflect emissions related to future earnings upon which market value is assessed (AMP Capital, 2016). In so doing, this study has captured some of the additional future carbon risk incremental to that captured in historic emissions.

Second, environmental accounting literature asserts that proactive environmental strategies help companies anticipate the implementation of future policies and social pressures, and represent dynamic capabilities that have implications for financial performance through enhanced reputation and lowering of costs (Aragon-Correa & Sharma, 2003). Setting these arguments within Hart's (1995) natural resource-based view of the firm (NRBV), which predicts that proactive environmental strategies and financial performance are interrelated, PCRs may represent capabilities that are inimitable and provide firms with economic benefits and competitive advantages. We develop a unique forward-looking measure of carbon proactivity that allows investors to assess the PCRs from publically available information, and considers the valuation effects of PCRs. The findings suggest that markets consider how firms position themselves to manage future carbon risks through PCRs when assessing a firm's carbon liability.

Third, the use of the Australian setting allows one to consider the implications of uncertainty when investors assess the carbon responses of firms in market valuations. In deciding whether PCRs represent a resource, Miller and Shamsie (1996) note that the extent to which "an asset can be considered a resource will depend as much on the *context enveloping an organisation* as on the properties of the asset itself" (1996: 539, italics added). The Australian context is one that has mandatory reporting of emissions, but lacks consequences or penalties for high emissions, and is characterised by uncertain carbon policy. A consideration of this context underpins the PCR measure. In particular, Miller and Shamsie (1996) argue that during periods of high uncertainty firms will focus on creating knowledge-based capabilities which are hard for competitors to mimic because they embody specific skills that may not be well understood due to their intangible nature. Consequently, the PCR proxy used in this study focuses on these knowledge based intangible carbon capabilities by adopting a mix of both market and non-market responses of firms that demonstrate these capabilities.

The paper is organised as follows. The institutional setting is summarised and the literature is reviewed in Section 2. Section 3 outlines our methods and describes our data, while Section 4 discusses the operationalisation of the measures for other carbon risk exposure and PCRs. The main results of our analysis are presented and discussed in Section 5. Concluding comments follow.

2 Institutional Setting and Literature Review

2.1 Institutional setting

Carbon policy in Australia has been erratic. For example, the 2011 Clean Energy Act saw the introduction on 1 July 2012 of a fixed carbon price equal to $23 per tonne of carbon dioxide equivalent (tCO2-e) greenhouse gases. However, in 2014, the Senate repealed the Clean Energy Act, 2011 and the *Direct Action Plan* replaced the policy. This policy differs to the previous regulation in that it sees the government pay entities to reduce their emissions, as opposed to requiring entities to pay for the right to emit. The absence of a sustained and unilateral national policy on carbon has resulted in a significant amount of uncertainty for Australian corporates. In conjunction with the Direct Action Plan, the National Greenhouse and Energy Reporting Act, 2007 (hereafter, NGER scheme) provides the mechanism for mandatory corporate reporting of GHG emissions and energy consumption and production.

In the absence of formal carbon-related reporting requirements for Australian firms, aside from the NGER scheme, corporates look to several global disclosure guidelines for direction on best practice disclosures. These include the Greenhouse Gas (GHG) Protocol, the International Integrated Reporting Council’s IR Framework, the Climate Disclosure Standards Board’s (CDSB) Climate Change Reporting Framework, as well as the CDP (formerly known as the Carbon Disclosure Project) recommendations. The latest iteration of the CDSB Framework is aligned with the G20’s Task Force on Climate-related Financial Disclosures (TCFD), which endeavours to develop voluntary disclosure guidelines for climate-related financial risk disclosures across different industries. Aside from the mandated emissions reporting, the voluntary nature of carbon risk reporting in Australia has resulted in considerable variation in disclosure practices across organisations (Foerster et al., 2017; Haque, Deegan, & Inglis, 2016; Subramaniam, Collier, Cooper, Wines, Leung, Ferguson et al., 2012).

2.2 Literature review

The majority of studies on the carbon risk-firm value relation focus on the financial effects resulting largely from regulatory differences associated with high carbon emissions (Chapple, Clarkson, & Gold, 2013; Clarkson et al., 2015; Griffin et al., 2017; Matsumura et al., 2014). Using carbon emissions data as a proxy for environmental performance, the extant literature shows that the capital markets appear to impose a penalty on companies that are high carbon emitters due to the perceived presence of economically significant off-balance sheet liabilities (Chapple et al., 2013; Clarkson et al., 2015; Griffin et al., 2017; Matsumura et al., 2014). These documented penalties suggest that investors perceive these liabilities as not providing long lasting economic benefits, and as a result, carbon emissions are negatively associated with firm value. For instance, Chapple et al. (2013) used a sample of firms from Australia in anticipation of the implementation of an ETS to examine the value relevance of the scheme. Using an Ohlson-based model and an event study they found that the market appears to assess a market value penalty of between 7% and 10% of market capitalization for those firms with the highest carbon intensity measures.

Matsumura et al. (2014) used carbon emissions data obtained from the CDP to examine the relationship between voluntarily disclosed non-financial disclosures and firm value for a sample of firms within the S&P 500, with the estimated relationship implying an assessed penalty of $212 per ton of carbon emissions. They argue that these results are consistent with the notion that capital markets impound both carbon emissions and the act of voluntarily disclosing them into firm valuations.

Similarly, Griffin et al. (2017) focus on a sample of S&P 500 firms that voluntarily disclose their emissions through the CDP. The results of their valuation based methodology and event study find that greenhouse gas emissions (GHG) are negatively associated with firm value, and in particular, that this negative association is more pronounced for firms that are more carbon-intensive. They document a market-implied penalty of $78.8 per ton of GHG emissions.

Evidence within the literature also reveals that the markets use other information such as holding sufficient emissions allowances (Clarkson et al., 2015; Johnston, Sefcik, & Soderstrom, 2008) and other environmental performance information (Clarkson, Li, & Richardson, 2004) to assist in their interpretation of carbon emissions data when assessing the magnitude of the penalty. To illustrate, Clarkson et al. (2015) use a sample of firms trading under the European Union ETS and an Ohlson-based model to determine whether the market values the portion of total emissions covered by free allowances differently to the shortfall not covered by allowances. This study challenged the underlying assumption of previous studies that the market assesses the firms’ carbon liabilities uniformly based on its actual emissions, and posited that where firms’ emissions are adequately covered by allowances it is indicative of efficiency by management. Documenting an assessed penalty of €75 per tonne of uncovered carbon emissions, they find evidence to suggest that this penalty is mitigated by the ability of the firm to pass on the future compliance costs to consumers and by the firm's carbon performance relative to their industry peers. Their findings suggest that it is unlikely that the valuation impact of carbon emissions would be homogenous across industrial sectors or firms. They note that these cross-sectional variations in how the market responds to the uncovered emissions are not explained by the historical emissions of the firms and observe that the coefficient on abnormal earnings indicates an abnormal earnings multiplier of between five and eight.

Literature suggests that the level of carbon risk exposure is determined by various factors including carbon intensity (Chapple et al., 2013; Clarkson et al., 2015; Griffin et al., 2017; Matsumura et al., 2014), carbon dependency (Busch & Pinkse, 2012; Sprengel & Busch, 2011) and the competitive environment (Clarkson et al., 2015). These exposures in turn, lead to adverse effects on financial performance (Al-Tuwaijri, Christensen, & Hughes, 2004; Sharfman & Fernando, 2008), operations (Busch & Hoffmann, 2007; Jeswani et al., 2008) or reputation (Kytle & Ruggie, 2005) of the firm. Nevertheless, there is a paucity of research that examines the carbon risk-firm value relationship by focusing on carbon risk aside from carbon emissions risk. Here, we find studies such as Ansar, Caldecott, and Tilbury (2013), who use case study analysis, surveys and interviews with various experts to focus on the potential effects of the fossil fuel divestment campaign on a firm's reputation. They find evidence to suggest indirect effects on market value, noting that divestment campaigns may lead to stigmatisation of firms, thus increasing uncertainty about future cash flows.

Our study extends existing literature on the value relevance of carbon-risk exposures by explicitly considering an additional measure for carbon risk exposure, 'other carbon risk', which attempts to capture a firm's exposure to financial, operational and reputational risks arising from carbon dependency and visibility. Firms with high carbon dependency may be exposed to greater operational risks due to their inability to substitute fossil fuels with alternative energy sources (Hoffmann & Busch, 2008). Socio-political factors such as changing consumer demands may also adversely affect the future competitiveness of highly carbon dependent firms. Likewise, firms that are perceived to be irresponsible on carbon-related issues may suffer negative impacts on their competitiveness position, ultimately leading to the detriment of future cash flows (Ansar et al., 2013; Kytle & Ruggie, 2005). Therefore, based on prior literature, we argue that high carbon risk exposure results in greater uncertainty about future cash flows, and thus adversely affects firm valuations.

Industry research (AMP Capital, 2016; Deutsche Bank, 2009; IRRCi & Trucost, 2009) suggests that the valuation impact of carbon emissions depends not only on a firm's total emissions but on additional factors such as firms' ability to pass-on costs and policy outcomes (e.g. allocation of emission allowances). Additionally, because carbon emissions presents a unique set of risks for firms between and within the various industrial sectors, different managerial responses relating to carbon are required for firms to manage their risk exposure.

Focusing on the carbon response of firms, identified from publically available information, may therefore reveal incremental information about future carbon and financial performance. There are a raft of studies within the business strategy literature that have developed typologies of environmental/climate change strategies and responses. Aragon-Correa and Sharma (2003) summarise these responses as falling along a continuum ranging from reactive to proactive in nature. Our study focuses on *carbon proactivity*, the operationalisation of which has been based on the carbon responses that demonstrate the anticipatory or pre-meditated positioning of the firm that enables timely responses to carbon risks that arise in the future. For example, diversification relates to the ability of the firm to adapt by exercising operational flexibility (Busch, 2011) through diversification from its reliance on fossil fuels. Firms that are able to diversify using alternative energy and fuels may be at a competitive advantage over their less diversifiable counterparts in a carbon-constrained future, as they become less dependent on carbon.

Hence, carbon proactivity is of interest for three reasons. First, PCRs are forward-looking in nature and therefore are potentially more informative than historic emissions for assessment of future financial performance. Prior literature asserts that proactive environmental strategies help companies anticipate the implementation of *future* policies and social pressures, and have implications for financial performance through enhanced reputation and lowering of costs (Aragon-Correa & Sharma, 2003; Boiral, 2006; Hart, 1995).

Second, it is argued that PCRs represent inimitable capabilities that may yield competitive advantages for the firm. The natural resource based view of the firm (NRBV) has been employed in a number of studies to provide a link between environmental and financial performance (Cormier & Magnan, 2015; Qiu, Shaukat, & Tharyan, 2016; Russo & Fouts, 1997). The NRBV proposes that valuable, costly-to-copy capabilities and firm resources provide a key source of sustainable competitive advantage (Hart, 1995). Moreover Aragón-Correa, Marcus, and Hurtado-Torres (2016) suggest that proactive environmental (carbon) responses represent such an inimitable capability. Therefore, the NRBV offers a theoretical link to suggest that proactive environmental strategies, under which proactive carbon responses fall, may be economically beneficial, particularly if these responses are communicated to outside parties. Firms that are not actively pursuing similar environmental policies would find it difficult to mimic a genuine competitor if that firm followed a quality signalling strategy. Due to the inimitable and forward-looking nature of PCRs it is expected that these are likely to provide longer lasting benefits by positioning firms to more easily comply with and respond to increasing external pressures to reduce emissions (Boiral, 2006).

Third, not all firms are able to respond to carbon risks through a reduction in carbon emissions due to the lack of viable alternatives for firms to substitute fossil fuel use (Busch &

Hoffmann, 2007). Stakeholder theory requires firms to manage their most powerful stakeholders (Deegan & Blomquist, 2006; Neu, Warsame, & Pedwell, 1998; Ullmann, 1985). This may involve reassuring investors that despite a firm's current inability to materially reduce emissions, the firm is cognisant of and actively seeking ways to affect changes to their carbon profile in the future through PCRs. Therefore, it may be beneficial for firms to communicate their carbon responses to avoid the withdrawal of investor support. Clarkson et al.'s (2015) study which finds evidence that holding emissions allowances mitigates the market penalty on carbon suggests that investors may assess a smaller penalty for firms that are demonstrating PCRs aside from emissions reductions. On this basis, it is possible that PCRs are perceived by sophisticated investors to be material to their investment decisions.

From the literature and industry, we learn that there is a demand for additional forward-looking information beyond the provision of carbon emissions to inform capital markets assessment of firm market value, and in particular the magnitude of the carbon penalty. This raises the question: do these PCRs represent other value relevant information that is able to mitigate the carbon penalty imposed on high carbon-emitting firms? Knowledge of a firm's PCR(s) allows capital markets to more accurately forecast future financial performance and to develop a more informed perception of the carbon risk exposure of the firm. Setting these arguments within the NRBV (Hart, 1995), which predicts that proactive environmental strategies and financial performance are interrelated, we argue that PCRs represent capabilities that are inimitable and provide firms with economic benefits and competitive advantages.

In summary, we argue that in light of the above discussion PCRs may explain, at least in part, the cross-sectional variation in carbon-related market penalties for high emitting firms. Since investors are interested in future performance of firms, and assuming that carbon response impacts carbon performance, we propose that publically available information that reveals these responses may be used by capital markets in assessing the magnitude of the carbon penalty. We therefore argue that investors will value PCRs in the context of carbon risk exposure, resulting in at least a partial mitigation of the penalties assigned to high emitting firms.

3 Research Method

3.1 Econometric Models

The aim of this study is to revisit the valuation relevance of carbon risk exposure, using a broader notion of a firm's carbon profile. Specifically, we examine the valuation relevance of a firm's carbon profile using a modified Ohlson valuation model that has previously been employed by Clarkson et al. (2015) and Hsu and Wang (2013). The Collins et al. (1997) modification of the Ohlson valuation is used, which relates the market value of the firm to book value of its equity and earnings. The advantage of using this form of the model is that it does not require an estimation of abnormal earnings that is dependent on an estimation of cost of capital (Clarkson et al., 2015). All regression equations are estimated using pooled ordinary least squares (OLS), and robust standard errors clustered at the firm level are employed to address heteroscedasticity.

Initially, we investigate separately the valuation relevance of the two components of a firm's carbon profile that is additional to a firm's historical carbon emissions. The general form of the two econometric models we use are as follows:

$$MV = \beta_0 + \beta_1 BV + \beta_2 EARN + \beta_3 TCO2 + \beta_4 OCREXP + \varepsilon \quad (1)$$

$$MV = \beta_0 + \beta_1 BV + \beta_2 EARN + \beta_3 TCO2 + \beta_4 PCR + \beta_5 PCR*TCO2 + \varepsilon \quad (2)$$

where:

MV is the market value of common equity, calculated as the number of shares outstanding multiplied by the price per share of the firm's common stock at fiscal year-end[4,5]; *BV* is the book value of common equity at fiscal year-end; *EARN* is earnings before extraordinary items for the relevant fiscal year; *TCO2* is measured using absolute carbon emissions expressed as millions of tonnes of CO2-equivalent per year; *OCREXP* is a proxy for other carbon risk exposure based on carbon dependency and visibility in the carbon arena; and *PCR* is a proxy for anticipatory proactive carbon responses that position the firm to enable timely responses to future carbon risks. The development of the *OCREXP* and *PCR* proxies is outlined in section 3.3.

Within the context of model (1), we predict a negative coefficient on *OCREXP* (i.e. $\beta_4 < 0$). This expectation is consistent with firms with higher exposure to other carbon risks in the form of carbon dependency and greater visibility within the carbon arena, incurring a larger valuation penalty that is additional to the documented penalty on a firm's historical carbon emissions (*TCO2*). In relation to model (2), we have no prediction in relation to the coefficient on *PCR* (i.e. β_4 =?). It is not clear from prior research and the interviews with managers and analysts that proactive carbon responses, encompassing actions and/or decisions that position a firm to respond to future carbon risks on a timely basis, are valued by the market outside the context of a firm's carbon risk exposure. Following on, we do expect a positive coefficient on the interaction term, *PCR * TCO2*, consistent with the proposition that the negative impact of a firm's carbon risk exposure, in this case proxied by its historical carbon emissions, is

[4] As there is no resolution on the most appropriate date to use for determining market value, regressions are also run using alternative dates for price data producing results that are qualitatively and quantitatively the same. Specifically MV on last trading day of February following financial year (to coincide with publication of NGER data) and 3 months after financial year-end are used as sensitivity tests consistent with previous studies that have considered the value relevance of emissions data and/or environmental performance (Barth & McNichols, 1994; Chapple et al., 2013; Clarkson et al., 2015; Matsumura et al., 2014).

[5] In line with Clarkson et al. (2015) and Matsumura et al. (2014) market value is not scaled in primary analysis resulting in coefficients that are economically meaningful.

mitigated for firms with a greater investment of their resources in and building of capabilities around proactive carbon responses (i.e. $\beta_5 < 0$).

For completeness, we also consider the valuation relevance of both components of a firm's carbon profile within the one model as follows:

$$MV = \beta_0 + \beta_1 BV + \beta_2 EARN + \beta_3 TCO2 + \beta_4 OCREXP + \beta_4 PCR + \beta_5 PCR*TCO2 + \beta_6 PCR*OCREXP + \varepsilon \quad (3)$$

In the context of model (3), consistent with our expectations that the broader measure of a firm's carbon profile beyond just a firm's historical carbon emission is value relevant, our expectations explained in relation to models (1) and (2) do not change. That is, we expect a negative coefficient on *OCREXP* that is in addition to the valuation penalty captured by historical carbon emissions (i.e. $\beta_4 < 0$).We also expect that proactive carbon responses mitigate the valuation penalties associated with both *OCREXP* and *TCO2*. That is, we predict positive coefficients on the interaction terms *PCR*TCO2* (i.e. $\beta_5 < 0$) and *PCR*OCREXP* (i.e. $\beta_6 < 0$).

3.2 Sample

Our sample comprises 122 firm-year observations (51 firms) drawn from the high carbon emitting sectors of Energy, Materials, Industrials and Utilities[6] that are listed on the ASX200 with the necessary financial and market data in the Thomson Reuters Datastream database, as well as carbon emissions data from the National Greenhouse Energy Reporting (NGER) database[7] over the period 2014 to 2016. Firms from high emissions sectors are the focus of our paper since they are more likely to have higher exposure to carbon risks with a material impact on firm value.[8] Additionally, since we rely on publicly available data to

[6] These sectors were identified using the 2 digit GICS classification codes of 10, 15, 20 and 55.

[7] The Australian Government's Clean Energy Regulator (CER) publishes emissions data annually on 28 February for the previous reporting period, which covers the period 1 July to 30 June. Under the NGER scheme, the CER only publishes data about registered corporations that exceed thresholds. With effect from 1 July 2010, the applicable threshold is for corporations that have total scope 1 and scope 2 emissions equal to or greater than 50 kilotonnes CO2-e, or which exceed the facility threshold of 25 kilotonnes CO2-e (scope 1 and 2), or produce energy of 100 terajoules or more, or consume 100 terajoules or more of energy.

[8] Energy, materials, utilities, and industrials account for 96% of emissions reported in the 2014 NGER database (Australian Government, 2015).

measure a firm's carbon profile and there is a significant body of evidence that the information environment of large firms is richer (including self-disclosures) (Cowen, Ferreri, & Parker, 1987; Gray, Kouhy, & Lavers, 1995; Neu et al., 1998; Patten, 1991), we draw our sample firms from the ASX200 containing the largest 200 listed firms by market capitalisation. The sample period begins in 2014 when the Australian Government's current carbon regulation, The Direct Action Plan, came into effect. Table 1 provides an overview of the sample selection outcomes. From Panel A, there are 239 ASX200 firms from the energy, industrials, materials and utilities sectors. Of these observations, 122 have the necessary emissions data and market and financial data for analysis as shown in Panel B.

[Insert Table 1 here]

Table 2 presents descriptive statistics for the sample of 122 firm-year observations. From Panel A, there is reasonable cross-sectional variation in firm characteristics. For example, market value (MV) has a mean (median) value of $10.848 billion ($3.033 billion), with a range from $245 million to $191.024 billion. Likewise, the mean (median) value for book value (BV) and earnings (EARN) is $6.627 billion ($2.361 billion) and $269 million ($109 million) respectively, with the values ranging from $259 million to $83.955 billion and -$8.781 billion to $15.138 billion respectively. Similar cross-sectional variation is evident in the return on assets (ROA) with mean (median) value of 5.5% (5.4%), and values ranging from -31.4% to 29.4%. Likewise, size has a mean (median) value of $14.849 billion ($15.011 billion) and values ranging from $4.710 billion to $18.113 billion.

There is reasonable cross-sectional variation in carbon-related measures within the sample. Specifically, the mean volume of carbon emissions of 2.687 million tonnes of CO2 differs to the median emissions of 0.599 million tonnes of CO2 indicating that the emissions data is positively skewed (as many firms reported lower emissions volumes). Carbon-risk exposure that is incremental to that already captured in emissions (*OCREXP*), has a median value of 1, out of a maximum possible score of 5, with the range of scores extending between 0 and 5. The proactive carbon response (*PCR*) measure shows a median value of 16, with scores ranging from 1 to 48 points. Panel B of Table 2 shows that this pattern is repeated across all sectors, however the largest emitting firms and the firms with the most proactive carbon responses are found in the utilities sector with mean (median) carbon emissions of 10.797 (10.961) million tonnes and median *PCR* score of 24 points. Further, analysis by sector shows that Energy and Utilities ranks as the most exposed to other carbon risks with a median score of 3 points and values ranging from 2 points to 4 points. In contrast, Industrials are the lowest emitting sector with mean (median) emissions of 961 (224) million tonnes and corresponds with the highest emissions reductions with a median (range) score of 4 (0-9) points, and lowest other carbon-risk exposure with a median (range) score of zero (0 to 2) points.

[Insert Table 2 here]

3.3 Operationalisation of the Firm's Carbon Profile

We conducted 28 semi-structured interviews with financial statement preparers and five with financial statement users to inform the development of our two proxies for a firm's carbon profile that are operationalised via publicly available data on firms. In particular, the aim of the interviews with statement preparers was to identify what they perceived as proactive carbon responses – that is, the actions and/or decisions aimed at positioning their firms to adapt to future carbon risks on a timely basis – and where they would likely disclose this data about their firm, or seek it in relation to industry peers. Additionally, the interviews explored what the statement preparers perceived as carbon risk beyond just historical carbon emissions. Similarly, the interviews with financial statement users investigated what they perceived as carbon-related risk for firms, what they identified as a proactive carbon response, and what type of publicly available data they used to assess a firm's carbon profile.

Interview protocols guiding the semi-structured interviews were developed using the existing literature on the potential components of carbon risk, as well as potential proactive carbon responses. In addition, the protocols were informed from a consideration of international carbon reporting frameworks including the GRI G4 framework, the CDP questionnaire (CDP, 2014) and regulatory requirements (ASIC, 2013; Australian Securities Exchange, 2014). The protocols were pre-tested on three senior managers from the manufacturing and transport sectors, and three academics external to the project[9] to ensure that the interview prompts were understandable and addressed the aims of data collection.

Interviewees were recruited via a combination of convenience sampling using known contacts, and cold calling over the period February 2016 to March 2017. Potential financial statement preparer interviewees were identified as managers with the title of sustainability/environmental manager, investor communication or risk management within ASX200 firms in the Energy, Materials, Industrials and Utilities sectors that reported emissions under the NGER framework. A total of 28 managers from seven firms agreed to participate in the interview process. Table 3 provides demographic details of manager interviews by company type, management level, and position held.

[Insert Table 3 here]

Potential financial statement users were identified as ESG analysts with experience working with Australian firms. A search of the LinkedIn platform[10] for sell-side analysts from superannuation companies, investment houses and investment research organisations with the title of ESG or sustainability analyst resulted in the identification of 21 potential interviewees,

[9] The three academics were from the Global Change Institute at the University of Queensland, which is a collaborative hub of researchers working to address climate change impacts and population growth.

[10] LinkedIn is an internet-based business-networking forum that allows members to connect with one another through its social networking platform.

of which five agreed to participate in interviews. Table 4 provides demographic details of the position held, type of organisation and experience of the ESG analyst interviewees.

[Insert Table 4 here]

All interviews were recorded and transcribed with the exception of three for whom detailed hand notes were made. Data were analysed using the three sub processes of data reduction, data reduction and conclusion drawing recommended by (Miles, Huberman, & Saldana, 2014). Using NVIVO 11 software and a 'start list' of codes (Miles et al., 2014) the interview data was organised around two primary themes relating to carbon-risk exposure and proactive carbon responses.[11] A check-coding strategy was employed whereby coding was checked at regular intervals to ensure internal consistency of coding.

3.3.1 Other Carbon Risk

Our proxy for other carbon risk exposure, *OCREXP*, shown in Figure 1, is constructed based on two components, (*DEPEND* and *VISIB*) and ranges from a minimum score of zero to a maximum score of five. The first component, *DEPEND* measures the extent to which a firm is dependent on carbon due to the nature of its products (*CARBPROD*) or due to its supply chain position (*SSCHPOS*). Product related carbon dependency encompasses the risk associated with producing and/or trading in carbon-based products, which include the stranding of assets (Ansar et al., 2013; Carbon Tracker Initiative, 2013), and declining demand for their products (Busch & Hoffmann, 2007). We operationalise *CARBPROD* using description of operations from annual reports and corporate websites. Specifically, firms that extract, process and/or retail oil, gas or coal, are awarded one point, and firms that engage in generation of

[11] Coding was undertaken by a single researcher, however, another researcher coded a randomly selected four-page portion of a transcript using the coding scheme and decision rules. Discrepancies were discussed resulting in refinement of decision rules and collapsing of some codes. The process was repeated, and using a proportion agreement method (Miles et al., 2014) whereby the total number of agreements over the total number of agreements and disagreements was calculated, resulted in an inter-coder reliability ratio of 92.1%.

fossil fuel based energy are also awarded one point under this item, with a maximum score possible for *CARBPROD* of 2 points.

The second component of dependency, supply chain position, captures exposure to carbon risks associated with being near the top of the supply chain, where there is a limited pool of suppliers from which to source low carbon technologies. An ESG analyst explains the issue:

> *"…looking at companies or industries that don't necessarily have high carbon emissions themselves, but they have a supply chain that is very highly carbon intensive, so even when regulations bite, that will then put prices up for their suppliers, which then will flow down through to them, in terms of their costs of goods sold."*

We operationalise *SSCHPOS* by analysing the Operating and Financial Review section of annual reports supplemented by company websites to identify the main activities of the firms to distinguish between business-to-business (B2B) and business to customer (B2C) firms. Here, firms that operate B2B are allocated a single point, while firms that operate B2C are scored zero.

The second component of *OCREXP* captures the visibility (*VISIB*) of the firm in the carbon arena and the associated exposure to reputation. Two proxies (*ANFWG* and *CONTROV*) are used to identify the visibility of firms. The first proxy, analyst following (*ANFWG*), is used to identify the extent to which firms are under scrutiny from sophisticated investors in line with Bushee, Core, Guay, and Hamm (2010). This item is scored one point for firms followed by a greater number of analysts than the sector median in each year, and zero otherwise. The second proxy, *CONTROV* measures the presence of carbon controversies, where carbon controversies are any negative media attention relating to a firm's production of, or reliance on, carbon-emitting fossil fuels. To illustrate the materiality of this type of carbon-related visibility, a manager observed that:

> "*We are a high profile industry and a high profile company, so we're always in the news – usually for the right reasons – but if we weren't focused on or addressing our contribution to climate change, then I think that we could be subject to a significant backlash as a result of that.*"

Carbon controversies are identified from a search of the ASSET4 ESG and Factiva databases.[12] Firms having at least one carbon controversy during the twelve months prior to the release of NGER data are awarded a single point.

[Insert Figure 1 here]

3.3.2 Proactive Carbon Responses

Our proxy for proactive carbon responses comprises five dimensions which are summarised in Figure 2. They include: a demonstrated awareness of carbon risks and issues (14 indicators); carbon leadership in pursuing carbon management activities (10 indicators); demonstrated adaptability to uncertainty in relation to regulation, stakeholder demand and technological developments (13 indicators); responses undertaken to develop and maintain stakeholder trust (17 indicators); and linking beneficial outcomes to carbon responses (3 indicators).[13]

We operationalise the 57-item PCR index using hand-collected data from publically available data sources including firms' annual reports, sustainability reports (or equivalent), corporate websites, the NGER database, CDP responses, NGO websites, LinkedIn, Factiva, Dow Jones Sustainability Index, FTSE4GOOD index, UN Global Compact list of signatories, We Mean Business coalition website, and relevant government databases[14] that reveal the involvement of firms in offsetting activities. The index was developed in an iterative process following consultation with and feedback from two researchers, and three rounds of pilot

[12] Using FACTIVA, broad search terms were used to identify both controversies and other aspects of the PCR index. These included: carbon, climate change, fossil fuel, coal, gas, lignite, greenhouse gas, GHG, emissions, clean energy, renewable energy, renewables, solar, wind, hydro.

[13] We use unweighted dimensions to avoid subjectivity in assigning weights. However, for robustness, all regressions were run using equally weighted scores for each dimension, yielding results that were quantitatively and qualitatively the same.

[14] These include the Australian Government's Emissions Reduction Fund (ERF) database, New South Wales Energy Saving Scheme (ESS) database, and Victoria Energy Efficiency Target (VEET) database.

testing to refine decision rules and clarify data sources. An overview of the components of the PCR index and scoring rules is presented in Appendix A.

[Insert Figure 2 here]

The first dimension, *AWARE*, measures the *demonstrated* awareness and understanding that can be inferred from publically available information. The 14 indicators in this category are grouped according to four sub-categories, which include the act of disclosing, identification of carbon risks, wider view and understanding, and having a carbon plan).[15] To illustrate, a manager interviewee described this demonstrated awareness as follows:

> *"I think that what stakeholders want is a plan to address climate change and if you've got a coherent plan then I think that the reputational risk can be mitigated."*

The second dimension, leadership (*LSHIP*), ranks firms according to the extent to which they respond to carbon risks through the establishment of strong carbon leadership in perusing carbon management initiatives. The ten indicators in this category measure the demonstrated carbon leadership that is revealed through a firm's governance structures that can be identified in public channels. An example is carbon-related rather than general environmental-related KPIs for managers' compensation.

The third dimension, *ADAPT*, relates to the firm's demonstrated ability to respond appropriately to regulatory uncertainty, changing stakeholder demand and technological uncertainty. The thirteen indicators that are used to measure the adaptability of the firm are categorised according to three sub categories of collaboration and research, economic modelling and diversification. As an example, an analyst interviewee explained how economic modelling is perceived to mitigate future carbon risks:

> *"…they're doing innovative things, such as - not necessarily technological, but organisational- so instituting an internal carbon price, conducting public scenario*

[15] Analysts indicated that firms exposed to or anticipating exposure to material carbon risks have plans in place to respond to these carbon risks. Communicating these plans to external stakeholders reveals that firms are aware of these risks and are actively positioning themselves to manage them.

> *analysis like BHP have done, using different pricing models around the world, showing that they are genuinely engaging the issue and are recognising the risks."*

The fourth dimension of the index focuses on the publically observable carbon responses undertaken towards developing and maintaining stakeholder trust (*STKHTR*). The 17 indicators in *STKHTR* are categorised into accountability and credibility. A manager interviewee described the importance of building this trust with external parties and how it can be determined from public disclosures:

> "*If you want to work out whether a company is genuine or not, look who is working with them, and do those organisations have credit. This all comes down to trust... Trust not only in a company – do they consistently put out the same things pushing in the same direction – but trust in who they're engaging with.*"

The final dimension of the PCR index, carbon response outcomes (*CROUT*) is most closely related to the notion of carbon performance referred to in extant literature; however, there are distinct differences. Specifically the seven indicators in *CROUT* are categorised according to emissions reductions and linking outcomes to specified carbon responses. Emissions reductions capture efficient management of the stock of emissions, demonstrated through incremental *improvements* (changes) in carbon emissions volumes, while linking specific carbon responses to outcomes focuses on the *beneficial outcomes* (consequences) of carbon responses.

The index was tested for reliability and validity using rank order correlations and determining Cronbach alphas. From this, it emerged that emissions reductions did not possess internal consistency with the remaining dimensions of the index,[16] and as a result we omitted it from the PCR index, reducing the total score on the fifth dimension (*CROUT*) from 14 to 5 points and the total index from 102 to 93 points. However, on the basis of prior research, which

[16] Reliability estimates within each of the five dimensions of PCR were conducted, yielding Cronbach alphas of above 0.90 on all dimensions with the exception of carbon response outcomes (CROUT), which has a Cronbach alpha of 0.230. Removing emissions reductions (*EMRED*) from CROUT resulted in an increase in alpha on CROUT to 0.857. Based on the reliability of the index, we exclude items relating to emissions reductions from the PCR index for all subsequent empirical tests.

suggests that emissions reductions are a proactive response providing a foundation for future regulatory compliance and changing customer expectations (Busch & Hoffmann, 2007; Cai, Cui, & Jo, 2016; Jeswani et al., 2008), we do consider emission reductions as a separate carbon response to PCRs in our subsequent analyses.

3.3.3 Advantages of Developing Carbon Profile Proxies

We argue that there are four advantages to developing our own proxies for a firm's carbon profile and not relying on existing rankings and/or databases. First, despite the ease of access to KLD, CDP and Thomson Reuters ASSET4 data, prior research has shown that ESG ratings from different raters do not converge (Chatterji, Durand, Levine, & Touboul, 2016). Furthermore, these databases are limited as they cover a large number of varied sustainability issues. This is problematic as the materiality of sustainability issues is likely to differ between firms and industries, particularly since there is evidence of differential returns on investment from material and immaterial sustainability issues (Khan, Serafeim, & Yoon, 2016). That is, firms having higher ratings on material sustainability issues outperform firms with higher ratings on immaterial issues. This guidance on what is material decision-useful ESG data for investors is important when assessing carbon-risk exposure. Therefore, applying the PCR index therefore represents a response to the call by Khan et al. (2016) to extend their research on the materiality of sustainability responses and firm performance by using different data.

Second, the PCR index is based on a framework of carbon responses developed by proactive firms during a period of significant regulatory, stakeholder and technological uncertainty. In so doing, the PCR index deviates from business strategy literature by not focusing on specific tangible PCRs or activities and rather adopts a focus on the development of intangible capabilities as a carbon response. This emphasis derives from the manager interviews, which revealed that firms are investing significant resources into development of intangible carbon capabilities. Specifically, the interview findings suggest that due to uncertainty, managers are finding other ways to be proactive, aside from the 'greening' strategies typically thought to evidence proactivity (see for example Aragon-Correa & Sharma, 2003; Boiral, 2006; Clarkson, Li, Richardson, & Vasvari, 2011; Sharma & Vredenburg, 1998), through the development of these intangible carbon capabilities.

Third, the PCR index incorporates a mix of market and non-market carbon responses that extend beyond the reliance on historic carbon emissions data. Increasingly extant literature (Clarkson, Fang, Li, & Richardson, 2013; Hoffmann & Busch, 2008) and industry actors (AMP Capital, 2016; Ernst and Young, 2015; SAI Global, 2011) discern a need to identify forward-looking nature of carbon responses and consistent with this, activities such as making commitments and stakeholder engagement are developed at a conceptual level. Nevertheless, the operationalisation of these studies remains largely wedded to historic carbon emissions.

Fourth, the PCR index uses analyst insights to inform assessment of carbon responses from publically available information. This represents an important contribution to the extant literature by identifying the sources of publically available data frequently used by analysts and the type of information they seek in those channels. This translates into the inclusion of items in the index deemed to be decision-useful to sophisticated investors, rather than developing a best-practice carbon disclosure index.

4 Empirical Results

4.1 Other Carbon Risk Exposure

The results for our tests of whether other carbon risk is valuation relevant are presented in Table 5. The results for the base model, in which carbon emissions measured as millions of tonnes (*TCO2*) is included as the independent variable of interest, are reported in Panel A, column (1). Consistent with prior literature, which documents a valuation penalty for high emitting firms, the estimated coefficient on tonnes of carbon emissions is negative and significant at the 1% level (-0.360, *t* = -3.74). It is economically significant since the coefficient of -0.360 suggests an imposed penalty of $360 per tonne of carbon emissions. More generally, the results confirm prior expectations with both book value and earnings positively and significantly associated with firm value, with coefficients of 1.710 (*t* = 109.82) and 2.843 (*t* = 10.86) respectively. The magnitudes of the coefficients are consistent with expectations and norms associated with typical book value and earnings valuation models. The adjusted R^2 of 0.98 is also consistent with the norm of this type of valuation model (Clarkson et al., 2015). The magnitude, direction and significance of these coefficients are maintained across all models in this study. Therefore, the models appear to be reasonably well specified and provide a measure of confidence in interpreting the coefficients on the various other independent variables of interest.

[Insert Table 5 here]

We extend the base model first by replacing *TCO2* with *OCREXP* (column 2), and then including both measures of carbon-risk exposure (column 3). We find a negative coefficient of -1.147 for *OCREXP* that is weakly significant at the 10% level (*t* = -1.60, p = 0.085). When both measures of carbon risk exposure are included in the model (column 3) the estimated coefficients of -0.378 and -1.304 on *TCO2* and *OCREXP* respectively are both negative and significant at less than the 1% and 5% levels respectively. Therefore, the results are consistent with our predictions that the capital markets impose an additional valuation penalty on firms exposed to other forms of carbon risk, beyond that captured by historical carbon footprint. In fact, the results suggest that a one standard deviation change in other carbon risk exposure would result in a market penalty of $1.304 billion. Furthermore, these results indicate that other carbon risk exposure is incrementally informative in understanding the carbon risk exposure of firms.

We extend our investigation of the relation between a firm's market value and other carbon risk by considering the sub-components of our proxy for other carbon risk exposure – that is, carbon dependency and visibility within the carbon arena. The results are reported in Panel B of Table 5. First, we consider the association between a firm's market value and the sub-components of *VISIB* and *DEPEND* separately and the results are presented in columns (1) and (2); and then we include both *VISIB* and *DEPEND* within the one model, with the results presented in column (3). We find that the coefficient on *VISIB* is insignificant (column (1)), while the estimated coefficient on *DEPEND* is negative and significant (t=-3.09, p=0.003) (column (2)). When included simultaneously in the model, we find that the estimated coefficient on *DEPEND* remains negative and significant (t= -2.92, p = 0.005), while the coefficient on *VISIB* remains insignificant. Here, this result is economically significant since a one standard deviation increase in *DEPEND* suggests a $4.611 billion valuation penalty on firms with high carbon dependency. Additionally, a test of linear restrictions reveals that *TCO2* and *DEPEND* are equally significant contributors to carbon-risk exposure (F=8.45, p=0.0054). On balance, these results suggest that investors perceive that carbon dependency is a significant component of a firm's carbon-risk exposure. In contrast, visibility within the carbon arena, on its own, is not a significant contributor to other carbon risk.

A firm's carbon dependency is based on its carbon-product risk (*CARBPROD*) and supply chain position (*SSCHPOS*). We investigate the effects of the individual components of *DEPEND* on firm value further and the results are reported in column (4). We include the individual components of *VISIB* – that is, the extent of analyst following (*ANFWG*) and carbon controversy involvement (*CONTROV*) – for completeness. Only the coefficient on *SSCHPOS* is negative and significant (t=-2.97, p= 0.024), suggesting that only supply chain position has a direct negative association with firm market value. This implies that firms operating predominantly business to business (B2B) are penalised by capital markets, which is consistent with the interviewee observations that supply chain position limits the firm's ability to respond to carbon risks. B2B firms typically have a smaller pool of both customers and suppliers with which to trade, which means that many of these middle businesses are constrained by the ability of available suppliers to offer products that support a transition to low carbon. Further, these constraints may also make it more difficult for B2B firms to pass on the costs of carbon. In contrast, B2C firms typically have a larger pool of suppliers and customers and therefore are more able to select carbon compliant suppliers and/or pass on carbon costs to their customers.

4.2 Proactive carbon responses

4.2.1 Proactive carbon responses and carbon risk exposure (proxied by carbon emissions)

The results for our tests of whether proactive carbon responses convey a competitive advantage that is valued by the market, thus mitigating, at least in part, the carbon risk market penalty are reported in Table 6. The first column of Panel A reports the results of estimating the model (2) including only proactive carbon response (*PCR*). The second column reports the results after the model is expanded to include *TCO2*. The third column reports the results after including the interaction term *PCR*TCO2*, and columns (4) to (6) show the differences in the results across years.

Consistent with our expectations, the estimated coefficient on *PCR* is not significant in any of the variations across columns (1)-(3). This result suggests that proactive carbon responses in and of themselves are not valuation relevant. Turning to the valuation implications of *PCR* when considered in the context of a firm's carbon performance, the coefficient on the interaction term *PCR*TCO2* reported in column (3) is positive and significant (0.021, $t = 2.97$ $p = .000$). This result suggests that capital markets are sensitive to proactive carbon responses, but only for high emitting firms. A test of linear restrictions reveals the net coefficient to be negative and significant (-1.248 + 0.021 = -1.227; F=15.12, p=0.000), suggesting that a proactive carbon response only partly mitigates the carbon valuation penalty.

We examine the effect across time to determine whether the change in carbon regulation that occurred during 2014 had any effect on how investors perceive PCRs. The final three columns in Panel A show the differences in the results across years. The estimated coefficient on *TCO2* increases across the three-year period of the study. This result is consistent with capital markets imposing greater market penalties on high emitting firms, despite the repeal of the carbon tax in Australia in 2014. Temporal differences are also evident in both the magnitude and significance of the interaction term *PCR*TCO2*. The estimated coefficient on *PCR*TCO2* is 0.004 and not significant in 2014, but increases to 0.022 (p = 0.025) and 0.037 (p = 0.030) in 2015 and 2016 respectively. The steady increase in magnitude of the coefficient on *PCR*TCO2* over the sample period suggests that, on average, investors are increasingly impounding PCRs, which are evident from publically available information, into their firm valuation decisions for high emitting firms. Thus, it appears that, in the absence of stable carbon regulation, investors are increasingly attempting to assess the future effects of carbon risks for firms, and are rewarding their PCRs to potential future carbon-risk exposure. That is, investors value the development of intangible carbon-related capabilities.

Analysing the interaction of *PCR* with *TCO2* further, we examine investors' perceptions of how the different dimensions of proactive carbon responses interact separately with historical carbon emissions. From Panel B, we observe that the estimated coefficients on the interaction terms *ADAPT*TCO2*, *LSHIP*TCO2* and *STKHTR*TCO2* are positive and significant, with coefficients of 0.034 (t = 1.96, p = 0.036), 0.076 (t = 3.66, p = 0.001) and 0.040 (t= 2.30, p = 0.025) respectively. A test of linear restrictions capturing the marginal valuation impact of *TCO2* conditional on *ADAPT* reveals the net coefficient to be negative (-1.004 + 0.034 = 11.22; p = 0.002). Likewise, a test of the linear restriction reveals that the sum of the coefficient estimates for *TCO2* and LSHIP*TCO2 is significant at the 1% level (-0.879 + 0.076 = 24.06; p = 0.000). Similar results emerge when testing the linear restrictions on TCO2 and STKHTR*TCO2, with the sum of the coefficient estimates significant at the 1% level (-0.965 + 0.040 = 19.59, p = 0.0001). These results imply that the valuation penalty imposed on high carbon emitting firms is partially mitigated by these specific types of PCRs. In contrast, coefficients on the interaction terms *AWARE*TCO2* and *PCRLINK*TCO2* are not significant. These results are interesting because adaptability, leadership and stakeholder trust provide greater insight into *future* carbon-risk management, whereas *PCRLINK* measures the extent to which firms explain how carbon responses have affected emissions performance, and therefore arguably represent an *historic* measure. From the interviews, analysts indicated that carbon risk awareness is a necessary starting point for managing carbon risks, however these results suggest that awareness is not sufficient to mitigate the assessed valuation penalties on high carbon emitters.

[Insert Table 6 here]

4.2.2 Analysis of proactive carbon responses on other carbon risk exposure

Previously, we document that capital markets penalise firms exposed to other forms of carbon risk that are additional to that captured in emissions. As a result, we investigate whether PCRs mitigate the valuation penalty attributable to other carbon risk by estimating model (3). The results of our tests are reported in Panel C of Table 6. The coefficient on *OCREXP* is again negative and significant (-1.613, t=-2.22), however, although the estimated coefficient on the interaction term *PCR*OCREXP* is positive, it is statistically insignificant. In contrast, the interaction term *PCR*TCO2* retains direction, magnitude and statistical significance consistent with prior models. In all, these results suggest that while proactive carbon responses identified from publically available information mitigate the valuation penalty imposed in relation to historic carbon emissions, proactive carbon responses do not mitigate the penalty attributable to other carbon-risk exposure.

We also consider the individual components of *OCREXP* to determine whether PCRs are utilised by investors to mitigate the documented penalty on carbon dependency. The results are presented in Panel D of 6. First, *OCREXP* is decomposed into visibility (*VISIB*) and carbon dependency (*DEPEND*) and the composite PCR variable is added, with the results reported in column (1). Again, if *PCR* is able to mitigate the valuation penalty assigned to *DEPEND*, we expect the coefficient on *PCR*DEPEND* to be positive and significant.

Consistent with our earlier results, the estimated coefficients on *TCO2* and *DEPEND* remain negative and significant with coefficients of -0.470 (t =-3.13) and -4.380 (t = 2.49) respectively, while *VISIB* is negative and non-significant. Also, consistent with our earlier result, PCR remains positive and non-significant. We include the interaction term *PCR*DEPEND* and report the results in column (2). The estimated coefficient on the interaction term *PCR*DEPEND* is not significant, providing further evidence that proactive carbon responses and their composite parts do not mitigate the assigned penalty on firms that are more carbon dependent.

Following on, *PCR* is decomposed into its five dimensions, and regressions are run interacting each dimension separately with *DEPEND* to test if any one dimension of proactivity mitigates the penalty on carbon dependency. These results are presented in columns (3) through (7) of Panel C. We find that the estimated coefficients on each of the interactions between the sub-components of *PCRs* and *DEPEND* are not significant. The coefficients on *TCO2* remains negative and significant in all regressions, confirming previous findings that markets assess a valuation penalty on high emitters. These results would suggest that no individual aspect of proactivity is able to mitigate the valuation penalty imposed on firms that are more carbon dependent. Since the proactivity measures used in this study are concerned primarily with intangible responses, it may be the case that they have little capacity to change the inherent nature of carbon dependent firms.

To summarise, our results suggest that proactive carbon responses identified from publically available information partially mitigate the valuation penalty imposed on high carbon emitters. Furthermore, we argue that the results suggest that in the absence of stable carbon regulation, investors increasingly attempting to assess the future effects of carbon risks for firms, rewarding proactive carbon responses to potential future carbon-risk exposure for firms with greater exposure to carbon risk. In particular, adaptability, carbon leadership and stakeholder trust are found to be specific aspects of proactivity that partially mitigate the valuation penalty imposed on high carbon emitting firms.

4.3 Management of stock of emissions

In testing the reliability of the PCR Index, two types of carbon responses emerged, namely PCRs and the management of stock of emissions. We consider here the valuation effects of management of the stock of emissions as an alternative carbon response. Previous literature asserts that the management of carbon emissions volumes revealed through carbon performance is indicative of operational efficiency (Busch, 2011). It is likely that high carbon emitters will have to pay in the future either through direct pricing or indirectly through policies to ensure regulatory approval. An explicit price placed on carbon will result in increased cost of emissions, which will drive up input costs such as energy and raw materials as suppliers upstream attempt to pass on their costs. Thus, it can be argued that ongoing emissions reductions likely results in improved future financial performance through reductions in energy costs. Further, given that literature already documents a valuation penalty for high emitting firms, we argue that firms that are able to demonstrate the effective management of emissions are at an economic advantage compared to their less efficient industry peers. As such, we predict that capital markets would respond favourably to efficient emissions management by high emitting firms.

To test whether management of stock of emissions is impounded by capital markets in assessing firm market value, we modify equation (2) by replacing PCR with the variable *EMRED* as follows:

$$MV = \beta_0 + \beta_1 BV + \beta_2 EARN + \beta_3 TCO2 + \beta_4 EMRED + \beta_5 EMRED * TCO2 + \varepsilon \quad (4)$$

Where *EMRED* captures incremental *improvements* (changes) in carbon emissions volumes over time that demonstrate efficient emissions management[17]. It is calculated as a composite score of four measures of emissions reductions. The first two measures award 2 points each to firms that attain reductions in their absolute scope 1 and scope 2 emissions relative to the previous year. Consistent with prior literature these two indicators have been included to capture the downward trend in scope 1 and scope 2 emissions over time (Clarkson et al., 2013; Dobler, Lajili, & Zeghal, 2015; Herbohn, Walker, & Loo, 2014; Tang & Luo, 2014). The third indicator captures firm specific reductions in carbon intensities. Carbon intensity is calculated using total scope 1 and scope 2 emissions over market capitalisation in line with interview findings of how analysts calculate carbon intensity. Reductions in carbon intensity are measured relative to a base year.[18] Following Luo and Tang (2014) this item is given the highest weighting in assessing *EMRED* with a maximum score of three points, as it takes into account variations in firm size and operations and therefore is more comparable between reporting periods and across firms (Hoffmann & Busch, 2008). Several prior studies have also considered carbon intensities relative to sector peers (Clarkson, Li, Richardson, &

[17] As shown in table 2, scores on *EMRED* ranged from 0 to 9 points, with a mean (median) value of 4.402 (4) for the pooled sample of 122 firms.

[18] In case of spurious data in the base year, a three-year average is calculated. The earliest available data published by the Australian Government's Clean Energy Regulator on mandatorily reported carbon emissions data covers the 2008-2009 period. Therefore, the three-year period including 2009, 2010 and 2011 is used to determine the baseline carbon intensities for the firms in the sample. Absolute emissions are not considered in this multi-year period, as it is likely that variables other than carbon responses could affect emissions volumes. Because of data availability, 23 firm-year observations are lost in this process.

Vasvari, 2008; Clarkson, Overell, & Chapple, 2011; Luo & Tang, 2014; Tang & Luo, 2014). Thus, the fourth indicator awards two points if a firm's carbon intensity is lower than the median of its two-digit GICS sector.

From equation (4) we predict that emissions reductions mitigate the valuation penalty imposed on high carbon emitting firms. That is, we expect the coefficient on β_5 in equation (4) to be positive.

Table 7 shows the results for the regression model in equation (4) using *EMRED* as an alternative carbon response to *PCR*. From Panel A, we find a positive coefficient of 0.282 (t =1.88, p = 0.066) on *EMRED*, however, looking across the years, it is apparent that this result is driven largely by the response of markets in 2016. Specifically, in 2016 the coefficient on *EMRED* is 0.742 (t = 1.92, p = .066), although our results are only weakly significant at the 10% level. Of equal interest are the results for the interaction term *EMRED*TCO2*. Here we find that the results are not statistically significant. Thus, the results only provide very weak evidence that investors consider emissions reductions when estimating the market value of all firms. Furthermore, there is no evidence to suggest that emissions reductions mitigate the valuation penalty imposed on high emitters. These findings support the view that emissions reductions have limited usefulness in assessing the future carbon performance of firms. This is because there is very little scope for firms that have already attained a high level of efficient emissions management to achieve further substantive emissions reductions. Moreover, they provide empirical evidence to support industry claims around the limitations of historic emissions to adequately anticipate emissions related to future earnings (AMP Capital, 2016).

[Insert Table 7 here]

From Panel B, we find no evidence of emissions reductions being informative for valuation purposes conditional on other carbon risk exposure. Again, using analysis across the years of the study to seek further insight on these results, we find non-significant results for

EMRED in all years. Moreover, interacting *EMRED* with *DEPEND* yielded non-significant results indicating that emissions reduction plays no role in mitigating the penalty on firms with high carbon dependency.

4.4 Sensitivity tests

We tested the robustness of the base model by using an alternate specification of the dependent variable. Specifically, as there is no resolution on the most appropriate date to use for determining market value, regressions are also run using price data three months after fiscal year-end (Chapple et al., 2013), and on the last trading day of February each year, to coincide with the release of NGER data (Clarkson et al., 2015). The untabulated results based on these dates are consistent with those reported for all analyses.

Further, following prior literature, we run the model using the alternative form:

$$P = \beta_0 + \beta_1 BVPS + \beta_2 EPS + \beta_3 CIPRANK + \beta_4 OCRERANK + \varepsilon \quad (5)$$

where the dependent variable *P* is the price per share at fiscal year-end, *BVPS* is book value per share at fiscal year-end; *EPS* is earnings per share; *CIPRANK* measures the intra industry/year percentile rank for carbon intensity of firms; *OCRERANK* measures the other carbon risk exposure score percentile ranking within industry and year. Here, the untabulated results are qualitatively and quantitatively the same as the primary results, with the exception of *OCRERANK*. Specifically, *OCRERANK*, while maintaining the sign and magnitude of coefficients, loses statistical significance. This is not surprising given that the unranked *OCREXP* variable only has a range of 0-5 and therefore ranking this variable may result in a loss of information.

5 Conclusion

In this study, we focus on high carbon-emitting firms in Australia to revisit the valuation relevance of a firm's carbon profile, by employing a broader notion of carbon profile that encompasses other carbon-risk exposure and PCRs. We use extant literature informed by interviews to develop measures for this expanded notion of a firm's carbon profile. From the interviews, and drawing on Hart's (1995) NRBV for sensemaking, this study presents PCRs as intangible carbon capabilities that may create competitive advantages, thereby positively affecting future financial performance.

Using a sample of 122 firm-year observations during the period 2014-2016, we document a penalty imposed on carbon dependent firms. Moreover, we find that PCRs partially mitigate the documented penalty imposed on high emitters. Specifically, we find that adaptability, carbon leadership and stakeholder trust are proactive capabilities that partially mitigate the emissions penalty. However, these PCRs are not able to mitigate the documented penalty on carbon dependency. Furthermore, we also find that emissions reductions are not effective in mitigating the carbon liability associated with high emitters. These findings are robust to different model specifications and proxy measures.

This study has several important implications. Firstly, they indicate that proactive firms are focused on developing knowledge-based intangible capabilities because of regulatory uncertainty and a resource culture in Australia. Secondly, the findings suggest that markets consider carbon intensity, carbon dependency and carbon visibility when assessing a firm's latent carbon liability, indicating that we have captured some of the additional future carbon risk incremental to that captured in historical emissions. Therefore, future research on carbon risk would benefit from considering both a broader notion of carbon risk exposure, and the context of the firm in determining what constitutes carbon proactivity.

Thirdly, the findings suggest that markets consider how firms position themselves to manage future carbon risks through PCRs when assessing a firm's carbon liability. Evidence that PCRs mitigate the valuation penalty suggest that it is economically worthwhile for managers to move beyond simple disclosure of emissions volumes and reductions to include other non-financial information that allow investors to better understand the carbon risk profile of firms. This resonates with the call of industry for firms to provide appropriate disclosures that demonstrate that they are assessing and managing their carbon risks (AMP Capital, 2016; Ernst and Young, 2017; Reputex, 2016). This also confirms the proposition of Clarkson et al. (2015) that investors do not assess carbon emissions uniformly, and extends their work to reveal that markets distinguish between less and more proactive firms in assessing firm market value. Finally, finding no evidence that emissions reductions are able to mitigate the documented penalty on high emitters provides empirical evidence to support industry claims around the limitations of historic emissions to adequately anticipate emissions related to future earnings (AMP Capital, 2016). This is important for Government regulators and policy setters in their future policy deliberations.

Our study opens up avenues for future research. The interviews did not cover all industries and it is likely that other factors may affect carbon responses in other settings. Furthermore, the Australian setting may be unique in that there is a strong resource culture, wherein investors are accepting of the nature of industries that are high-emitters. Moreover, mainstream and ESG investing currently make up a substantial proportion of investing in Australia compared to socially responsible investing. Therefore, the findings may not necessarily be generalised to other jurisdictions. Hence, future research could explore whether the carbon responses that comprise ‘proactivity’ in Australia are relevant in other jurisdictions. Finally, we did not find any evidence that proactivity is able to mitigate valuation penalties imposed on carbon dependent firms. Therefore future studies would benefit from exploring what factors are utilised by capital markets in mitigating the penalties assigned on high carbon dependent firms.

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Table 1 Frequency distribution for the number of firm observations by industry and year

Panel A: ASX200 firms at 28 February	2014	2015	2016	Total
Energy	17	14	8	39
Industrials	30	29	24	83
Materials	38	31	32	101
Utilities	6	5	5	16
	91	79	69	239
Panel B: ASX200 firms with emissions and PCR data				
Energy	6	6	4	16
Industrials	9	6	7	22
Materials	25	26	27	78
Utilities	2	2	2	6
Total	42	40	40	122

Table 2 Descriptive statistics for the pooled sample of 122 firm-year observations

Panel A: Firm characteristics for the pooled sample of 122 firm-year observations						
Variable	Obs	Mean	Median	Std. Dev.	Min	Max
MV	122	10.848	3.033	27.121	0.245	191.024
BV	122	6.627	2.361	14.680	0.259	83.955
EARN	122	0.269	0.109	1.933	-8.781	15.138
ROA	122	0.055	0.054	0.068	-0.314	0.294
SIZE	122	14.849	15.011	1.589	4.710	18.113
TCO2	122	2.687	0.599	4.876	0.056	19.929
OCREXP	122	1.623	1	0.999	0	5
PCR	122	17.836	16	12.786	1	48
EMRED	122	4.402	4	2.656	0	9
Panel B: Firm characteristics by sector						
Energy	Obs	Mean	Median	Std. Dev.	Min	Max
MV	16	10.398	8.572	9.479	1.065	31.273
BV	16	8.396	4.870	7.010	1.351	20.356
EARN	16	-0.004	0.020	1.120	-2.698	2.687
SIZE	16	15.334	15.621	1.277	13.498	17.003
ROA	16	0.018	0.031	0.093	-0.239	0.126
TCO2	16	5.784	2.910	6.252	0.056	18.105
OCREXP	16	2.875	3	0.885	2	5
PCR	16	23	22	12.442	5	41
EMRED	16	3.812	4	3.430	0	9

Materials	Obs	Mean	Median	Std. Dev.	Min	Max
MV	78	12.609	2.262	33.478	0.394	191.023
BV	78	7.410	1.703	17.952	0.259	83.955
EARN	78	0.367	0.102	2.334	-8.781	15.138
SIZE	78	14.611	14.584	1.769	4.710	18.113
ROA	78	0.066	0.062	0.070	-0.313	0.294
TCO2	78	1.914	0.377	3.745	0.056	18.487
OCREXP	78	1.590	1	0.692	1	4
PCR	78	15.526	14	11.886	1	46
EMRED	78	4.295	4	2.455	0	9
Industrials	Obs	Mean	Median	Std. Dev.	Min	Max
MV	22	5.774	4.766	4.4931	0.245	14.207
BV	22	2.817	2.312	1.8098	0.539	6.529
EARN	22	0.147	0.229	0.7242	-2.843	1.029
SIZE	22	15.218	15.143	1.0474	13.783	16.639
ROA	22	0.047	0.054	0.0339	-0.088	0.089
TCO2	22	0.961	0.224	1.5465	0.075	4.795
OCREXP	22	0.455	0	0.5096	0	2
PCR	22	20.366	24	11.858	1	36
EMRED	22	5.045	4	2.591	0	9
Utilities	Obs	Mean	Median	Std. Dev.	Min	Max
MV	6	7.753	6.929	3.435	4.475	13.015
BV	6	5.697	5.544	2.547	3.211	8.532
EARN	6	0.179	0.198	0.352	-0.408	0.570
SIZE	6	15.296	15.269	0.949	14.403	16.227
ROA	6	0.045	0.045	0.012	0.027	0.061
TCO2	6	10.797	10.961	10.005	1.485	19.929
OCREXP	6	3	3	0	3	4
PCR	6	24.833	24	21.683	2	48
EMRED	6	5	5.5	3.286	0	9

This table presents descriptive statistics for regression variables. In panel A, descriptive statistics are provided for the pooled sample of 122 firm-year observations. In Panel B, descriptive statistics are provided for the sample on a sector-by-sector basis.

Variable definitions: MV is market value of common equity (in billions of dollars), calculated as the number of shares outstanding multiplied by the price per share of the firm's common stock at fiscal year-end; BV is book value of common equity (in billions of dollars), at fiscal year-end; EARN is Earnings before extraordinary items (in billions of dollars), for the relevant fiscal year; SIZE is the natural logarithm of sales revenue; ROA is return on assets calculated as earnings before interest over beginning total assets less outside equity interests; TCO2 is Total scope 1 and scope 2 carbon emissions expressed as millions of tonnes of CO2-equivalent per year; OCREXP is other carbon risk exposure measured using OCREXP index as previously described; PCR is proactive carbon response measured using PCR index as previously described; *EMRED* measures reductions relative to the preceding year for absolute scope 1 emissions, absolute scope 2 emissions and carbon intensity (calculated as total scope 1 and 2 over market capitalisation (index items E55 to E58), with CI reductions measured relative to a base year, (calculated as average of 2009-2011), and relative to sector peers.

Table 3 Demographic details of Manager Interviewees:

Panel A: Manager Interviewees by company and functional level

Management level	Job Title	Company A	B	C	D	E	F	G	Total
Executive	CEO, CFO, COO, Exec GM	1	3		1			1	6
Senior	General Manager	2		3	1	1	1		8
Middle	Group Manager, BU Manager	3		2	2	4			11
Line	Eco Trader, Senior analyst	0		3					3
Totals		6	3	8	4	5	1	1	28
Sustainability		2		4	2	2	1	1	12
Investor relations		2	2	1		1			6
Operations		2	1	3	2	2			10
		6	3	8	4	5	1	1	28
Average length of interview in minutes									44
Minimum length of interview in minutes									24
Maximum length of interview in minutes									76

Panel B: Cross-section of organisations for Manager Interviews

Organisation	Sector	Market Capitalisation*	Total scope 1 & 2 emissions (t CO2e)†	No. of Interviews
Company A	Resources	< \$0.5B	< 0.1M‡	6
Company B	Resources	< \$0.5B	< 0.1M	3
Company C	Energy	> \$10B	> 5M	8
Company D	Transport	\$1 - 10B	2 – 5M	4
Company E	Energy	\$1 - 10B	> 5M	5
Company F	Energy	\$1 - 10B	2 – 5M	1
Company G	Materials	\$1 - 10B	> 5M	1
Total number of interviews				28

* All financial data obtained from Datanalysis as at 30 June 2016.

† Emissions data obtained from the 2014/2015 NGERs database. These data are only made publically available in February of the following year.

‡ The emission volumes of Company A were obtained from the internal records of the organisation, as the firm had de-registered from NGERs in 2014.

Table 4 Descriptive statistics of ESG Analysts by organisation and position

Type of Organisation	Job Title	Length of service in years
Investment House	ESG Assistant Analyst	5.5
Superannuation Fund	Senior Investment Analyst	8.5
Investment research	ESG Analyst	2.5
Superannuation Fund	ESG Manager, Investments	11
Investment House	Senior ESG Analyst	4
Average length of interview in minutes		46

Table 5 Regression results for other carbon risk exposure

Panel A: Basic regression of TCO2 and OCREXP			
	(1)	(2)	(3)
	MV	MV	MV
BV	1.710^{***}	1.679^{***}	1.744^{***}
	(109.82)	(44.04)	(80.11)
EARN	**2.843^{***}**	**2.799^{***}**	**2.833^{***}**
	(10.86)	(11.97)	(10.93)
TCO2	**-0.360^{***}**		**-0.378^{***}**
	(-3.74)		(-3.90)
OCREXP		-1.147	**-1.304^{*}**
		(-1.60)	(-2.20)
Adj R^2	0.9817	0.9802	0.9826
N	122	122	122

Panel B: Regression analysis of VISIB and DEPEND				
	(1)	(2)	(3)	(4)
	MV	MV	MV	Disaggregated OCREXP
BV	1.721^{***}	1.792^{***}	1.796^{***}	1.776^{***}
	(92.89)	(70.19)	(71.34)	(59.52)
EARN	2.829^{***}	2.829^{***}	2.821^{***}	2.839^{***}
	(11.26)	(11.25)	(11.36)	(11.31)
TCO2	**-0.359^{***}**	**-0.435^{***}**	**-0.432^{***}**	**-0.438^{***}**
	(-3.54)	(-4.99)	(-4.76)	(-4.18)
VISIB	-0.710		-0.434	
	(-1.32)		(-0.86)	
DEPEND		**-4.768^{**}**	**-4.611^{**}**	
		(-3.09)	(-2.92)	
ANFWG				-0.661
				(-0.75)
CONTROV				0.354
				(0.22)
CARBPROD				-3.108
				(-1.54)
SSCHPOS				**-5.493^{**}**
				(-2.97)
Adj R^2	0.9818	0.9836	0.9836	0.9826
N	122	122	122	122

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Variable definitions: BV is book value of common equity (in billions of dollars), at fiscal year-end; EARN is earnings before extraordinary items (in billions of dollars), for the relevant fiscal year; TCO2 is Total scope 1 and scope 2 carbon emissions expressed as millions of tonnes of CO2-equivalent per year; OCREXP is other carbon risk exposure measured using OCREXP index as previously described. ANFWG is a binary variable that scores one point to firms that are followed by a greater number of analysts than the sector median in each year, and 0 otherwise; CONTROV is a binary variable that scores one point for firms having at least one carbon controversy during the twelve months prior to the release of NGER data, 0 otherwise; CARBPROD measures carbon dependency of firm by awarding 1point to firms that extract, process and/or retail oil, gas or coal, and 1 point to firms engaged in fossil fuel energy generation; SSCHPOS is the supply chain position of firms, distinguishing between business to business (B2B) and business to customer (B2C) as their main trade partners, where B2B is scored as 1 and B2C as 0. In panel C, OCREXP (a) is total other carbon risk exposure measured using the OCREXP index; OCREXP (b) is other carbon risk exposure excluding analyst following; OCREXP (c) is other carbon risk exposure excluding carbon controversies. VISIB is calculated as the total of CONTROV + ANFWG; DEPEND is calculated as the total of CARBPROD and SSCHPOS

Each column shows the results from the pooled OLS regression with robust standard errors clustered at the firm level, and adjusting for industry fixed-effects and year-fixed effects

Table 6 Regression results for proactive carbon responses

Panel A : Regression results for PCR and tonnes of carbon emissions

	(1)	(2)	(3)	2014	2015	2016
	MV	MV	MV	MV	MV	MV
BV	1.665***	1.696***	1.689***	1.973***	1.661***	1.688***
	(32.76)	(60.27)	(63.83)	(13.28)	(38.34)	(31.14)
EARN	2.799***	2.869***	2.865***	1.808*	1.107	2.865***
	(11.45)	(10.73)	(10.56)	(2.35)	(1.31)	(6.78)
TCO2		**-0.430****	**-1.248*****	**-0.777***	**-1.369*****	**-1.909***
		(-2.94)	(-3.95)	(-1.97)	(-3.76)	(-2.41)
PCR	-0.026	0.050	0.033	-0.016	0.079	0.031
	(-0.46)	(0.72)	(0.48)	(-0.39)	(0.84)	(0.24)
PCR*TCO2			**0.021*****	0.004	**0.022***	**0.037***
			(2.97)	(0.37)	(2.51)	(2.31)
Adj R^2	0.9795	0.9820	0.9827	0.9924	0.9803	0.9646
N	122	122	122	42	40	40

Panel B : Regression results for disaggregated PCR and carbon emissions

	AWARE	ADAPT	LSHIP	STKHTR	PCRLINK
	MV	MV	MV	MV	MV
BV	1.714***	1.693***	1.726***	1.686***	1.715***
	(80.68)	(63.59)	(74.98)	(61.71)	(126.77)
EARN	2.835***	2.876***	2.805***	2.871***	2.866***
	(10.41)	(10.70)	(10.78)	(10.20)	(10.60)
TCO2	**-0.775***	**-1.004****	**-0.879*****	**-0.965*****	**-0.201***
	(-2.24)	(-3.29)	(-4.94)	(-4.31)	(-1.51)
AWARE	-0.110				
	(-0.98)				
AWARE*TCO2	0.031				
	(1.28)				
ADAPT		0.083			
		(0.59)			
ADAPT*TCO2		**0.034***			
		(1.96)			
LSHIP			-0.245		
			(-0.92)		
LSHIP*TCO2			**0.076*****		
			(3.66)		
STKHTR				0.097	
				(0.58)	
STKHTR*TCO2				**0.040***	
				(2.30)	
PCRLINK					0.057
					(0.17)
PCRLINK*TCO2					-0.072
					(-1.23)
Adj R^2	0.9818	0.9824	0.9826	0.9823	0.9815
N	122	122	122	122	122

Panel C: Regression results for PCR and OCREXP

	(1)	(2)
	MV	MV
BV	1.729***	1.721***
	(54.56)	(49.29)
EARN	2.863***	2.862***
	(10.90)	(10.69)
TCO2	**-0.462****	**-1.342*****
	(-3.10)	(-4.24)
PCR	0.058	0.029
	(0.85)	(0.41)
OCREXP	**-1.369***	**-1.613***
	(-2.31)	(-2.22)
PCR*TCO2		**0.023****
		(3.06)
PCR*OCREXP		0.008
		(0.29)
Adj R^2	0.9828	0.9838
N	122	122

Panel D: Regression results using disaggregated PCR and OCREXP							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	MV	MV	AWARE	ADAPT	LSHIP	STKHTR	PCRLNK
BV	1.785^{***}	1.775^{***}	**1.809^{***}**	**1.767^{***}**	**1.781^{***}**	**1.785^{***}**	**1.799^{***}**
	(40.81)	(42.09)	(65.96)	(49.73)	(39.08)	(41.04)	(65.20)
EARN	2.836^{***}	2.826^{***}	**2.803^{***}**	**2.883^{***}**	**2.817^{***}**	**2.831^{***}**	**2.827^{***}**
	(11.16)	(11.21)	(10.92)	(11.42)	(11.16)	(11.83)	(11.03)
TCO2	**-0.470^{**}**	**-1.336^{***}**	**-0.367^{**}**	**-0.557^{***}**	**-0.405^{**}**	**-0.456^{**}**	**-0.415^{***}**
	(-3.13)	(-3.69)	(-3.00)	(-3.68)	(-2.86)	(-3.15)	(-4.13)
PCR	0.029	0.016					
	(0.39)	(0.15)					
VISIB	-0.505	-0.636	-0.260	-0.447	-0.283	-0.577	-0.420
	(-0.98)	(-1.28)	(-0.59)	(-0.85)	(-0.58)	(-1.03)	(-0.87)
DEPEND	**-4.380^{*}**	-4.377	-4.114	**-6.967^{*}**	**-6.384^{**}**	-3.569	**-4.247^{*}**
	(-2.49)	(-1.63)	(-1.14)	(-2.44)	(-2.93)	(-1.41)	(-2.48)
PCR*TCO2		**0.023^{*}**					
		(2.53)					
PCR*DEPEND		-0.001					
		(-0.01)					
AWARE			-0.0548				
			(-0.21)				
AWARE *DEPEND			-0.0633				
			(-0.26)				
ADAPT				-0.171			
				(-0.69)			
ADAPT *DEPEND				0.242			
				(1.27)			
LSHIP					-0.710		
					(-1.19)		
LSHIP *DEPEND					0.468		
					(1.01)		
STKHTR						0.164	
						(0.63)	
STKHTR *DEPEND						-0.0666	
						(-0.33)	
PCRLNK							0.142
							(0.20)
PCRLNK*DEPEND							-0.217
							(-0.31)
Adj R^2	0.9835	0.9844	0.9836	0.9838	0.9837	0.9834	0.9833
N	122	122	122	122	122	122	122

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Variable definitions: Variable definitions: BV is book value of common equity (in billions of dollars), at fiscal year-end; EARN is earnings before extraordinary items (in billions of dollars), for the relevant fiscal year; TCO2 is Total scope 1 and scope 2 carbon emissions expressed as millions of tonnes of CO2-equivalent per year; PCR is proactive carbon responses using the PCR index as previously defined; PCR*TCO2 is an interaction term between PCR and TCO2; AWARE is a firm's demonstrated carbon awareness measured according to the PCR index; AWARE*TCO2 is an interaction term between AWARE and TCO2; ADAPT is a firm's demonstrated ability to adapt measured using the PCR index; ADAPT* TCO2 is an interaction term between ADAPT and TCO2; LSHIP is a firm's demonstrated level of carbon leadership measured using the PCR index; LSHIP* TCO2 is an interaction term between LSHIP and TCO2; STKHTR is a firm's level of stakeholder trust measured using the PCR index;

STKHTR* TCO2 is an interaction term between STKHTR and TCO2; PCRLNK is the extent to which a firm provides a link between their carbon responses and beneficial outcomes measured using the PCR index; PCRLNK* TCO2 is an interaction term between PCRLNK and TCO2; OCREXP is other carbon risk exposure measured using OCREXP index as previously described; PCR*OCREXP is an interaction term between PCR and OCREXP; VISIB is calculated as the total of carbon controversies and analyst following as described in the OCREXP index; DEPEND is calculated as the total of carbon product and supply chain position as described in OCREXP index; PCR*DEPEND is an interaction term between PCR and DEPEND; AWARE*DEPEND is an interaction term between AWARE and DEPEND; ADAPT*DEPEND is an interaction term between ADAPT and DEPEND; LSHIP*DEPEND is an interaction term between LSHIP and DEPEND; STKHTR*DEPEND is an interaction term between STKHTR and DEPEND; PCRLNK*DEPEND is an interaction term between PCRLNK and DEPEND.

Each column shows the results from the pooled OLS regression with robust standard errors clustered at the firm level, and adjusting for industry fixed-effects and year-fixed effects

Table 7 Regression results for EMRED for a sample of 122 firm-year observations for Australian companies over the period 2014 to 2016

Panel A: Regression results for EMRED and TCO2

	(1)	(2)	(3)	(4)	(5)
			2014	2015	2016
BV	1.708***	1.713***	1.991***	1.700***	1.698***
	(109.89)	(89.44)	(13.54)	(54.45)	(23.42)
EARN	2.827***	2.856***	1.764*	1.456	2.629***
	(9.69)	(10.78)	(2.28)	(1.13)	(5.34)
TCO2	-0.336***	-0.232*	-0.701**	-0.323**	0.005
	(-3.62)	(-2.23)	(-3.22)	(-3.23)	(0.02)
EMRED	0.184	0.282	0.167	0.220	0.742
	(1.21)	(1.88)	(1.11)	(0.77)	(1.92)
EMRED*TCO2		-0.047	0.003	-0.069	-0.087
		(-1.49)	(0.07)	(-1.02)	(-0.88)
Adj. R^2	0.9820	0.982	0.9928	0.9782	0.9655
N	122	122	42	40	40

Panel B: Regression results for *EMRED* and OCREXP

	(1)	(2)	(3)	(4)	(5)	(6)
			2014	2015	2016	
BV	1.704***	1.717***	1.998***	1.679***	1.700***	1.717***
	(89.20)	(74.55)	(12.47)	(57.52)	(20.67)	(65.40)
EARN	2.850***	2.827***	1.780*	1.426	2.662***	2.855***
	(10.36)	(10.14)	(2.25)	(1.55)	(4.75)	(10.95)
TCO2	-0.351**	-0.313*	-0.607**	-0.220	-0.241	-0.194
	(-2.84)	(-2.22)	(-3.22)	(-1.61)	(-0.93)	(-1.32)
EMRED	0.214	0.252	-0.075	0.066	0.682	0.242
	(1.50)	(1.28)	(-0.40)	(0.21)	(1.67)	(1.24)
OCREXP		-0.525	-2.309*	-1.418	-0.289	-0.983
		(-0.77)	(-2.10)	(-1.63)	(-0.36)	(-1.39)
EMRED*OCREXP		-0.055	0.314	0.093	-0.003	0.059
		(-0.31)	(1.43)	(0.60)	(-0.01)	(0.31)
EMRED*TCO2						-0.042
						(-1.13)
Adj R^2	0.9816	0.9817	0.9931	0.9797	0.9623	0.9818
N	122	122	42	40	40	122

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Variable definitions: BV is book value of common equity (in billions of dollars), at fiscal year-end; EARN is earnings before extraordinary items (in billions of dollars), for the relevant fiscal year; TCO2 is Total scope 1 and scope 2 carbon emissions expressed as millions of tonnes of CO2-equivalent per year; OCREXP is other carbon risk exposure measured using OCREXP index as previously described, *EMRED* is emissions reductions measured using a composite measure as previously described; *EMRED**TCO2 and *EMRED**OCREXP are interaction terms between *EMRED* and TCO2 and OCREXP respectively.

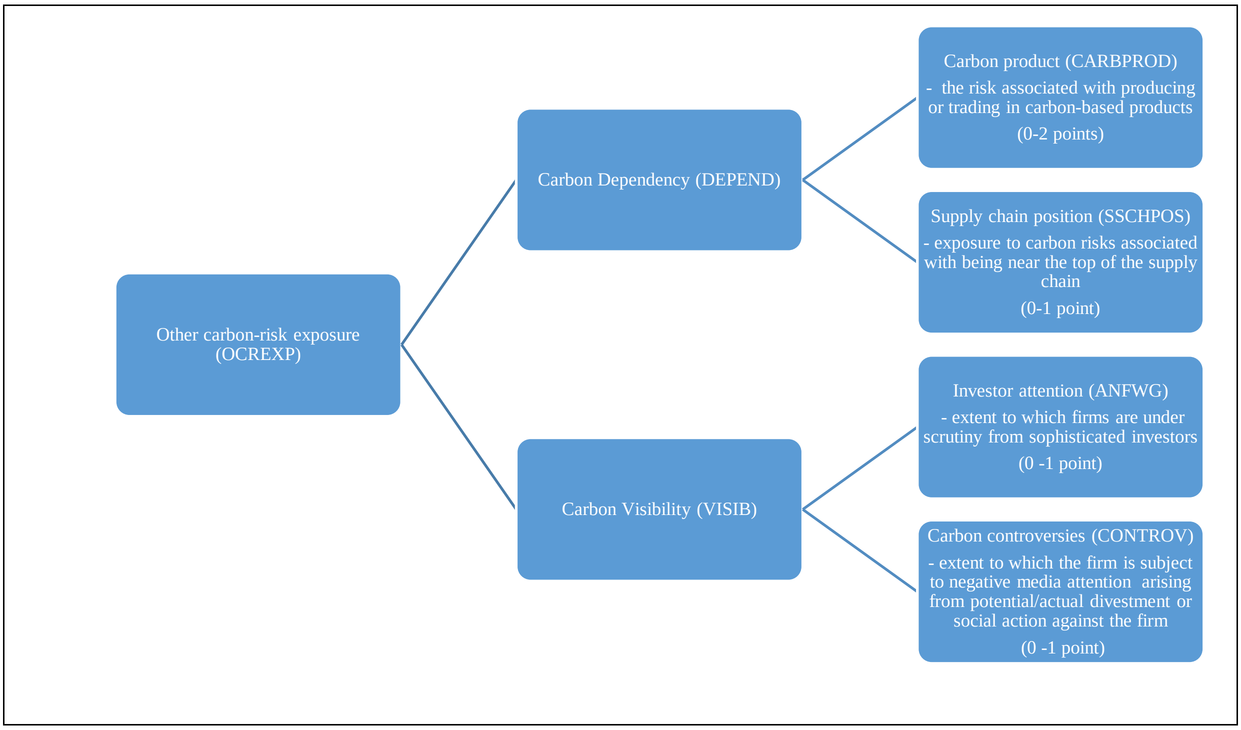

Figure 1 Composition of other carbon-risk exposure

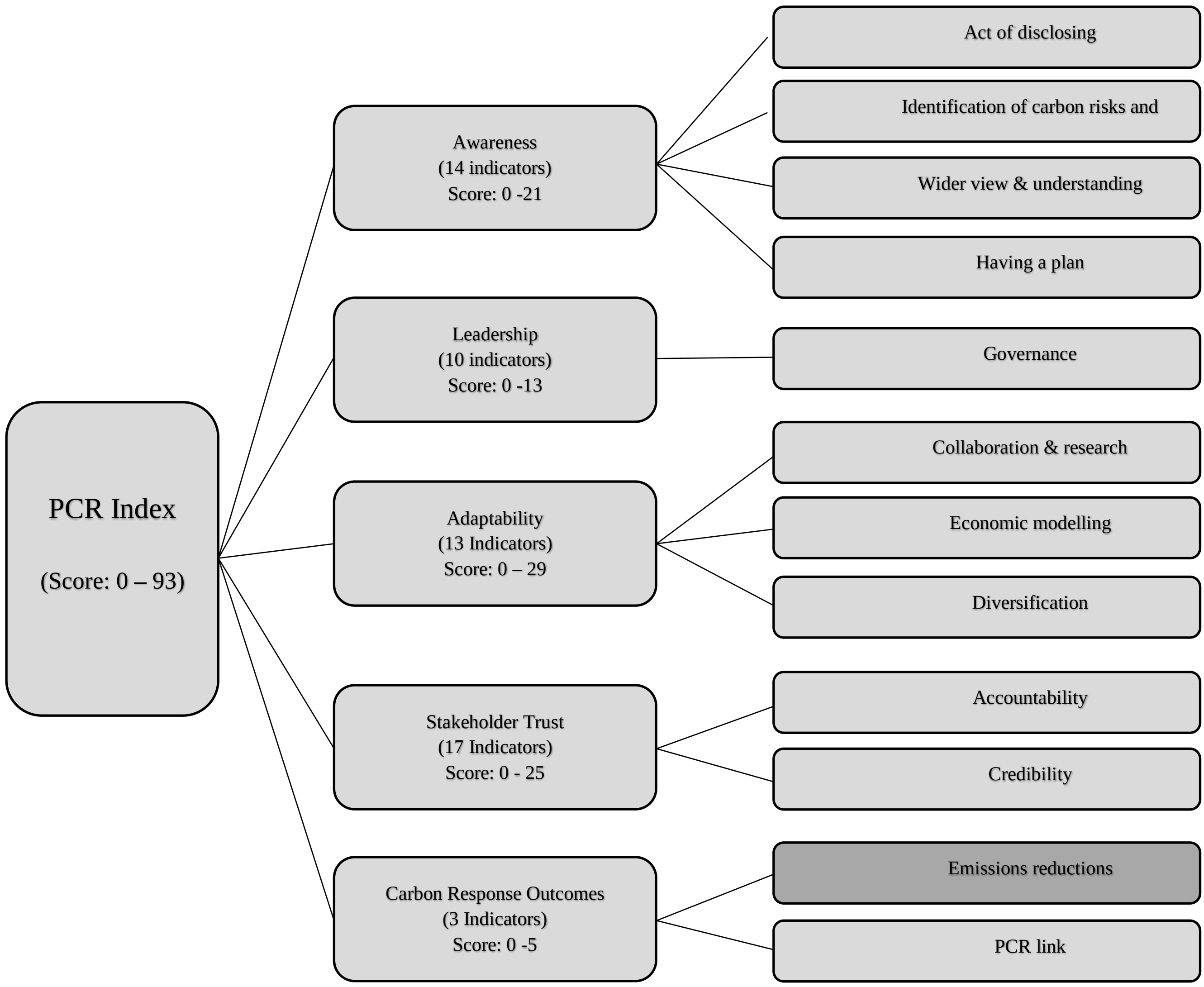

Figure 2 An overview of the PCR Index

Appendix A: Proactive Carbon Response Index

	Carbon specific Indicator	Scoring
CATEGORY A: AWARENESS & UNDERSTANDING (0-21)		
Act of Disclosing	1. Does the firm have an established carbon disclosure profile? (0 – 2)	0 = No; 2 = Yes for 5 consecutive years of disclosure
Identification of carbon risks and exposure	2. Has the firm identified any carbon risks? (0 – 1)	0 = No 1= Yes OR explanation provided as to why management does not consider the firm to be exposed to such risks and opportunities
	3. Has the firm identified the causes of the carbon risks i.e. physical, regulatory, reputational or other? (0 – 1)	0 = No; 1= Yes
	4. Has the firm identified the sources of carbon risk exposure i.e. emissions volumes (carbon intensity), fossil fuel reliance (carbon dependency), geographic location of operations or other? (0 – 1)	0 = No; 1= Yes
	5. Does the firm provide data that reflects proportion of fossil fuel assets in asset base? (0 – 1)	0 = No; 1= Yes
	6. Does the firm make known the proportion of revenue stream based on fossil fuels? (0 – 1)	0 = No; 1= Yes
	7. Does the firm make known its emissions on an equity basis? (0 – 3)	0 = No; 3= Yes
	8. Has the firm provided a description of the impact associated with the risk? (0 – 2)	0 = No; 1= Yes, but not detailed or quantified; 2 – Yes, detailed and quantified
	9. Has the firm indicated different timeframes associated with the carbon risks? (0 – 1)	0 = No; 1= Yes
Wider view & understanding	10. Does the firm acknowledge its role in addressing global and/or regional carbon emissions? (0 – 1)	0 = No; 1= Yes
	11. Does the firm identify the emissions attributable to operations/use outside of regional boundaries? (0 – 1)	0 = No; 1= Yes
	12. Has the firm provided carbon performance data at a disaggregated level? (0 – 1)	0 = No; 1= Yes
Plan/strategy	13. Does the firm indicate that they have a plan or framework for addressing carbon risks? (0 – 3)	0 = no evidence of any plan; 1 = evidence of specific initiatives to reduce emissions/exposure; 3 = formal plan articulated/published
	14. Is carbon risk management embedded in the strategy of the firm? (0-2)	0 = No; 1= Yes, description of how strategy has been influenced; 2 = Yes, description provided of how strategy has been influenced AND evidence that this provides economic benefits e.g. competitive advantage/cost savings/increased demand
CATEGORY B: LEADERSHIP (0 - 13)		
	15. Whether the CEO/chairperson articulates the organisation's views on the issue of climate change through publicly available documents such as annual reports, sustainability reports and websites. (0-2)	0 = No; 1= Yes in SR; 2 = Yes in Chairman's/Director's report
	16. Is there evidence that the Board has explicit oversight responsibility for carbon related issues? (0-1)	0 = No; 1= Yes
	17. Is there a specific board committee for climate change and GHG-related issues? (0-1)	0 = No; 1= Yes

	18. Is there a separate department/division or management positions responsible for carbon issues? (0-2)	0 = No; 1= Yes, management position; 2 = Yes, separate division and management position
	19. CEO/any of the Board members have previous carbon-related experience (0-1)	0 = No; 1= Yes
	20. Firm has a dynamic leader/thinker that addresses carbon issues publically (0-2)	0 = No; 1= Yes, but not CEO; 2 = Yes, CEO
	21. Does the firm have carbon-related research active staff? (0-1)	0 = No; 1= Yes
	22. Is executive compensation tied to attainment of emissions targets or other carbon performance criteria? (0-1)	0 = No; 1= Yes
	23. Does the firm provide financial incentives for management (apart from executives) for carbon-related issues? (0-1)	0 = No; 1= Yes
	24. Does the firm seek input of independent advisors on carbon-related issues? (0-1)	0 = No; 1= Yes
CATEGORY C: ADAPTABILITY (0 - 28)		
Collaboration and research	25. Does the firm indicate the existence of a sophisticated stakeholder engagement program? (0-2)	0 = No; 1= Yes, but no details given; 2 = Yes, and details given that indicate the purpose and/or nature of engagement
	26. Is the firm involved in political lobbying on carbon policy issues? (0-2)	0 = No; 1= Yes; 2 = verified from external sources
	27. Does the firm partner with other organisations for knowledge sharing? (0-2)	0 = No; 1= Yes; 2 = verified from external sources
	28. Has the firm invested in research and/or development of clean tech or other low-carbon initiatives? (0 – 5)	0 = No; 1 = Yes, but not quantified or explained; an additional point for each of the following: - Collaboration with industry association or sector peers; - Funding of research organisation; - Quantified dollar amounts spent; - New products/processes trialled
Economic modelling	29. Does the firm 'stress test' policy changes using different scenarios? (0-3)	0 = No; 3= Yes
	30. Does the firm use an internal price on carbon in modelling and forecasting? (0-2)	0 = No; 1= Yes; 2 = Yes and carbon price indicated, or valid reason for not disclosing carbon price is provided
Diversification	31. Has the firm launched new products/entered new markets? (o-1)	0 = No; 1= Yes
	32. Has the firm switched to renewable energy for some of its energy source? (0-1)	0 = No; 1= Yes
	33. Does the firm pursue product improvement initiatives? (0 – 3)	0 = No; 1 = Yes, indicates undertaken/plans to undertake but no examples evident; 2 = Yes, provides examples, but not linked to emissions reductions/outcomes; 3 = Yes, examples given and linked to emissions reductions outcomes
	34. Does the firm pursue process improvement initiatives? (0 – 3)	0 = No; 1 = Yes, indicates undertaken/plans to undertake but no examples evident; 2 = Yes, provides examples, but not linked to emissions reductions/outcomes; 3 = Yes, examples given and linked to emissions reductions outcomes
	35. Does the firm engage in activities/initiatives that help reduce downstream scope 3 emissions, e.g. distribution, use of sold products, end-of-life treatment of sold products? (0 – 2)	0 = No; 1= Yes; 2 = external evidence to confirm
	36. Does the firm engage in activities/initiatives that help reduce upstream scope 3 emissions, e.g. terms and conditions to parties in the supply chain regarding carbon practices, corporate travel, employee commuting, treatment of waste generated in operations? (0 – 1)	0 = No; 1= Yes
	37. Does the firm participate in offset activities and/or emission trading schemes? (0-1)	0 = No; 1= Yes
CATEGORY D: STAKEHOLDER TRUST (0 - 25)		
Accountability	38. Has the firm/CEO made commitments to manage carbon risks? (0-1)	0 = No; 1= Yes

	39. Has the firm delivered on prior commitments? (0- 2)	0 = No; 1= No, but explanation provided as to why this was not possible; 2 = Yes
	40. Has the firm indicated the setting of targets, and quantified these? (0- 3)	0 = No; 1= Yes 1 point for each of the following: Yes – absolute emissions reduction target set Yes – carbon intensity target set
	41. Has the firm met prior targets set? (0- 2)	0 = No; 1= No, but explanation provided as to why this was not possible; 2 = Yes
	42. Has the firm signed a public commitment to reduce emissions? (E.g. we mean business/OneFuture/World Bank's Putting a Price on Carbon). (0- 2)	0 = No; 1 = Yes, but no explanation of implications provided; 2 = Yes, and explanation of implications provided
	43. Has the firm signed a public commitment to manage broader ESG issues (e.g. UN Global Compact) (0 – 1)	0 = No; 1= Yes
Credibility	44. Has the carbon emissions data been externally verified? (0-1)	0 = No; 1= Yes
	45. Does the firm comply with GRI or similar or report to CDP? (0-2)	0 = No; 1= Yes for each body
	46. Has the firm been included in a sustainability index? (0- 3)	0 = No; 1 = Yes. If yes, an additional point if: • there is an upkeep requirement • explanation of implications provided
	47. Has the firm ceased any operations/processes and/or products/services due to carbon related risks? (0-1)	0 = No; 1= Yes
	48. Does the firm pursue multiple carbon initiatives? (0-1)	0 = No; 1= Yes
	49. Are the carbon initiatives of the firm consistent with the carbon strategy of the firm? (0-1)	0 = No; 1= Yes
	50. Has the firm revealed any strategic changes that support their carbon policy/strategy? E.g. appointment of key positions (0-1)	0 = No; 1= Yes
	51. Has the firm aligned itself with other firms/organisations that share similar views on carbon risk management and climate change? (0-1)	0 = No, or aligned with both proactive and defensive parties; 1= Yes
	52. Does the firm provide explanations for carbon-related decisions? (0-1)	0 = No; 1= Yes
	53. Does the firm make known assumptions in its carbon policy? (0-1)	0 = No; 1= Yes
	54. Is there evidence of greenwash in the disclosures of the firm e.g. disproportionate quantity of carbon disclosures to minority green activities; unusual carbon metrics? (0-1)	0 = Yes; 1 = No
CATEGORY E: CARBON RESPONSE OUTCOMES (0 – 14)		
Emissions reductions	55. Has the firm achieved reduction in absolute scope 1 emissions relative to the previous year? (0-2)	0 = No; 2= Yes (Omitted from final index)
	56. Has the firm achieved reduction in absolute scope 2 emissions relative to the previous year? (0- 2)	0 = No; 2= Yes (Omitted from final index)
	57. Has the firm achieved reduction in carbon intensities relative to the previous year? (0- 3)	0 = No; 3= Yes (Omitted from final index)
	58. Is the carbon intensity of the firm less than the sector median carbon intensity? (0- 2)	0 = No; 2= Yes (Omitted from final index)
PCR Link	59. Has the firm provided explanation for any changes in their absolute emissions? (0-1)	0 = No; 1= Yes
	60. Has the firm realised carbon reductions resulting from at least one of its carbon responses? (0- 2)	0 = No; 2= Yes
	61. Has the firm disclosed financial/economic benefits resulting from carbon response initiatives? (0- 2)	0 = No; 2= Yes