Investor Ownership and Carbon-Intensive Stocks: Who Holds the Carbon Risk Bomb?

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Abstract

Many investors still support carbon-intensive industries, even though there are various risks associated with such assets in regard to climate policies and stranded assets. This study aims to thoroughly examine which types of investors hold a higher proportion of carbon-intensive stocks in their portfolios. To identify high-polluting stocks we provide a classification of stocks based on three different categories related to industry sectors, carbon footprints and environmental scores. Data on year-end holdings from 2000-2015 is used to investigate whether different types of investors prefer or try to avoid carbon-intensive stocks in comparison to investments in peer companies. Our findings suggest that in particular government agencies have a higher exposure (around 50%) to polluting stocks in their portfolios, and typically also hold a high percentage of the total market capitalization of these firms. For all other investor types, comparable figures are significantly lower and range from 15% to 25% of their total investments. Interestingly, we do not find evidence suggesting a significant change over time in investor behavior with regard to holding carbon-intensive stocks in their portfolios. Our results are robust against different specifications of carbon-intensive companies and measures of ownership. Overall, our study offers a better understanding of the exposure to carbon-intensive stocks for auditors and investors. It also illustrates which parties have the ability to promote the reduction of carbon emissions by exercising voting rights. Additionally, the study provides fundamental information for policy makers to adjust regulations for the purpose of sustainability.

Keywords: Carbon Risk, Ownership Structure, GHG Emissions, Investor Behavior, Environmental Change, Carbon Constraints

JEL-Classification: G11, G32, Q56, O13, O33

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1 Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), Carbon Dioxide (CO_2) accounts for about three-quarter of global greenhouse gas (*GHG*) emissions and is likely to be the main driver for anthropogenic global warning (Intergovernmental Panel on Climate Change, 2015). As a result, policy makers around the world are considering various plans for reducing carbon emissions and aim to mitigate the possible consequences of rising temperatures. Even though there have been some significant achievements, such as the recent Paris agreement (European Comission, 2015), the implementation process of the agreed measures for carbon emission reductions is rather lengthy, difficult to enforce and subject to regular changes. The uncertainty about how upcoming measures on reducing carbon emissions will impact on a firm's future cash flow is often referred to as carbon risk (Dupré et al., 2015). It has been argued that the exposure to carbon risk for businesses and industries will be quite substantial (Carbon Tracker Initiative, 2013; Stern & Stern, 2007). Furthermore, the cost of carbon as well as the decarbonization of key industries is expected to lead to significant economic and societal changes in the long run, see, e.g. Doppelt (2017), Nordhaus (2017).

This study analyzes the exposure of different types of investors to carbon-intensive stocks, using an extensive ownership database for a large universe of stocks. We also examine possible changes in investment behavior and ownership with regard to carbon heavy industries in recent years. Thus, our study provides important insights on how different classes of investors are affected by carbon risk and whether these risks have already had an impact on investor behavior and holdings of carbon-intensive stocks.

Carbon risk is expected to have the most impact and relevance for companies with exposure to carbon emissions in any part of their business. On the one hand, a previously more or less costless or low cost activity had become costly, therefore companies face potential additional

costs due to taxes or the requirement to provide allowances based on their carbon emissions Cook (2009). On the other hand, firms also need to handle possible changes in customer demand or reputational risk related to being classified as unsustainable or high-polluting. The negative impact of firms' carbon emissions are becoming increasingly clear to society, such that companies, investors and policy decision-makers are taking a closer look at environmental disclosures. So far there is no clear answer on how carbon risk is taken into account for investment decisions. When investors begin to evaluate carbon risks in the same way they evaluate a firm's external market risks or management team, companies are likely to be rewarded or punished for the way they manage the risks from carbon emissions Gitman (2009). Not only firm's future cash flows but also accounting processes and procedures have been affected by environmental issues, as a result of the necessity to correctly consider and disclose carbon emissions, see, e.g., Hopwood (2009), Schaltegger and Csutora (2012), Steininger, Lininger, Meyer, Muñoz, and Schinko (2016), just to name a few.

Dealing with and accounting for carbon risk can therefore be seen as part of improving the overall business performance and long-term sustainable growth. In this context, a clear, informative and complete disclosure of risks related to carbon emissions of a company will be necessary, such that the decision process of a potential investor is supported. As suggested by Cho, Guidry, Hageman, and Patten (2012), there is a positive relationship between environmental disclosure and environmental reputation measures. The authors further suggest that higher level of environmental disclosure may offset the potentially negative effect of higher emissions on the reputation of a firm.

Furthermore, estimates suggest that in order to achieve the 2°C-goal set in Paris, about three-quarters of all remaining coal, oil and gas reserves should not be exploited (Le Quéré et al., 2015). Such a scenario will create so-called stranded assets, i.e. assets losing their economic value well ahead of their anticipated useful lifetime. Considering that this situation could create

a so-called “carbon bubble” in the valuation of carbon-intensive companies, there is an increasing interest in who invests in firms with high operational carbon risk. It is also important for policy makers to understand the ownership structure of these firms in order to develop appropriate measures.

This study provides important information on investor behavior with regard to high-polluting firms, relating to different strands of existing literature. First, our work is related to carbon risk research. Thus far academic literature has not contributed much to help investors with the costly challenge of cutting through the complexity of identifying an asset’s exposure to carbon risk. An exception includes the study by Hoffmann and Busch (2008) who develop four different indicators that help to assess a company’s contribution to climate change and its effort to manage its use of carbon emissions in a better way.

Second, our study relates to problems arising in accounting processes, due to restrictions on pollution, the regulation of carbon emissions and an increasing need for firms to disclose their environmental performance. The costs of debt for companies that do not appropriately disclose their carbon risk are expected to be higher with an increased exposure to carbon risk. This effect might be mitigated for companies that reveal their awareness of the risks they face Jung, Herbohn, and Clarkson (2018). Apparently this can be interpreted as differences in the attractiveness of a company for investors, if companies differ in terms of disclosing their carbon risk. But so far the existing, and more or less voluntary reporting requirements do not fully meet investors’ need (Sullivan & Gouldson, 2012).

Furthermore, this study also relates to research investigating the relationship between environmental and financial performance. In environmental science, scholars have illustrated that companies with higher pollution are typically less efficient in their operations, which harms their competitiveness and consequently minimizes their firm value. In addition to that, the eco-

efficiency concept suggests that modern and environmentally friendly production methods lead to developmental advantages (Ulshöfer & Bonnet, 2009). Based on this rationale, the expected relation between environmental performance, especially with respect to *GHG* emissions, and financial performance would be positive. However, the literature studying this relationship provides rather mixed conclusions. Using factor-model regression analysis, Derwall, Guenster, Bauer, and Koedijk (2005) and Oestreich and Tsiakas (2015) find conflicting results, with the first one suggesting an outperformance of good environmental performers and the second one better risk-return characteristics for bad ones. In earlier years Cohen, Fenn, and Naimon (1997) find neither a penalty nor a reward for investing in green portfolios. Studies performed by Ziegler, Busch, and Hoffmann (2011) and Liesen (2015) use the willingness of a company to disclose responses on climate change and *GHG* emissions, respectively, to set up different portfolios. Results from these studies suggest a better financial performance of disclosing firms. There is also a number of event studies, suggesting that qualitative signals, such as a company's attitude towards climate change, have a significant influence on stock returns, see, e.g., Jacobs, Singhal, and Subramanian (2010), Flammer (2013), Griffin and Sun (2012), Hsu and Wang (2013), Murguia and Lence (2015) and Veld-Merkoulova and Viteva (2016). However, results on the actual direction of the impact are rather ambiguous, with some studies suggesting a positive effect and others proposing a negative impact of climate change attitudes on the financial performance of a firm.

Another popular research method is to apply regression models, with financial performance of firms as the dependent variable and environmental performance as the key explanatory variable. Most of these studies find that high greenhouse gas emissions have a negative effect on market value and return on equity, see, Konar and Cohen (2001), King and Lenox (2001), Matsumura, Prakash, and Vera-Muñoz (2014), Aggarwal and Dow (2011), Saka and Oshika (2014), Misani and Pogutz (2015) and Gallego-Álvarez, Segura, and Martínez-Ferrero (2015). Kim, An, and

Kim (2015) and Chen and Silva Gao (2011) confirm this effect on the cost side, when associating higher *GHG* emissions with a higher cost on equity. An exception to these results is provided by Wang, Li, and Gao (2014), who find a positive effect of high *GHG* emissions on Tobin's Q for Australian firms. This could be explained by the importance of the mining industry for the Australian economy.

Lastly, academics examine whether decarbonization and the support of green investments are worth striving for with regard to the performance of investment portfolios. Similar to research on socially responsible investing (SRI), see, e.g., Mallin, Saadouni, and Briston (1995), Schumacher-Hummel (2005) and Derwall, Koedijk, and Ter Horst (2011), existing studies on green funds make use of different data sources, observation periods, methodological approaches and definitions. The findings of these studies either suggest empirical evidence in favor of (Chang, Nelson, & Doug Witte, 2012; Climent & Soriano, 2011) or against (Labatt & White, 2002; Mallett & Michelson, 2010; Muñoz, Vargas, & Marco, 2014) the superior performance of green investments.

The existing literature is mainly focused on examining which incentives, i.e. higher performance, investors might have to invest in carbon-intensive stocks. However, it often fails to provide auditors, investors and policy makers with an appropriate approach to identify carbon risk exposure. Furthermore, scholars have not yet explored the question of who actually 'holds the carbon risk bomb', i.e. which owner types are most invested in carbon-intensive stocks and, therefore, exposed to potential carbon risks. In particular, we combine information on firms with a high carbon risk exposure based on the Asset4 'Environmental, Social and Governance' (ESG) database with the Thomson Reuters Global Equity Ownership database that provides year-end holdings of these stocks for different types of investors. Thoroughly analyzing investor behavior and changes in the ownership structure of carbon intensive stocks for different investor types, our study contributes to the literature in several dimensions.

First, we define three different categories of carbon-intensive stocks that help to identify which companies can be considered as being 'dirty'. Our classification schemes are helpful for policy-makers, auditors or investors who aim to take into account a company's contribution to climate change or the exposure of an asset to carbon risk. Our constructed measures also complement existing indicators, see, e.g., Hoffmann and Busch (2008), that aim to help the classification of firms according to their carbon emissions or environmental performance. Second, to the best of our knowledge, we are the first to work with an extensive dataset of ownership structures from 2000-2015 in order to analyze investor behavior related to carbon-intensive stocks. With this study we therefore contribute to carbon risk research by showing in which portfolios the risks are bundled and which types of investors are more likely to hold high proportions of carbon-intensive stocks.

In particular, our study contributes to answering the following important research questions: How much carbon risk exposure can be observed in the portfolios of different investor types? What level of ownership - measured by the percentage of shares outstanding of a stock - do different investor types typically hold for the companies in their portfolios? How is the (CO_2-intensive) stock universe split between different owner types, and how are the different owner types invested in 'dirty' stocks in comparison to their normal investment behavior and portfolio allocation? Finally, we also examine whether the identification of potential carbon risks has already had an impact on investor behavior and the holdings of carbon-intensive stocks throughout the considered sample period.

Our findings show that from an owner type perspective, it is typically governments who have the highest exposures to carbon-intensive stocks in their portfolio (approximately 50% of portfolio value), whereas institutionals, hedge funds, individuals, investment advisors and mutual funds hold much lower exposures in these stocks (between 15% and 25%). Governments also hold the highest percentage of shares of 'dirty' stocks in their portfolio, holding on average

around 27% of shares outstanding of these firms. Interestingly, for the sample period from 2000 to 2015, our results do not suggest a significant change in investor behavior with regard to holding polluting stocks in their portfolio.

Regarding the overall ownership distribution of stocks in the CO2-intensive universe, we find that hedge funds and investment advisors form the biggest owner groups, having an ownership around 13% each. Moreover, we also provide more detailed information on the preferences and behavior of each type of investor. For example, we find that hedge funds, individuals, investment advisors and institutionals own statistically significant less carbon-intensive stocks in comparison to non-carbon-intensive stocks. By contrast, government agencies typically have more ownership in carbon-intensive stocks.

The remainder of the paper is set up as follows. Section 2 describes the methodology applied to identify carbon-intensive stocks and holdings. Section 3 provides a brief summary and key statistics of the data that is considered in the empirical analysis. Section 4 presents the results of our analysis, while Section 5 concludes and provides possible directions for future research.

2 Methodology and Definitions

To examine which investors are most exposed to carbon-intensive firms, it is necessary to identify companies that are significantly affected by carbon risk. So far, academic research has not contributed much to help investors to manage the complexity of identifying an asset's exposure to carbon risk. An exception is the study by Hoffmann and Busch (2008), where a number of indicators based on the amount of CO_2-emissions are defined. However, the Portfolio Carbon Initiative (PCI) set up by the United Nations Environment Finance Initiative (UNEP FI) develops a rather practical framework and argues that carbon risk does not only comprise quantifiable but also non-quantifiable components. In our study, we aim to gather a comprehensive picture of a firm's exposure to carbon risk, by including both quantitative and

qualitative aspects. Therefore, we define three metrics to classify carbon-intensive stocks: an industry-based carbon risk definition (industry affiliation), the carbon footprint of a company as well as a measure related to climate scoring.

2.1 Industry-based carbon risk definition (industry affiliation)

To break down the complexity of identifying carbon risk exposure, we start with the most intuitive approach. In a first step, we use the Thomson Reuters Business Classification (TRBC) to classify all stocks based on the industry they belong to. This seems reasonable, given that sectors are affected differently by the transformation into a carbon-constrained world (Labatt and White, 2002). This method has also been used in recent studies by Gallego-Álvarez et al. (2015) and Misani and Pogutz (2015) to select *GHG* sensitive firms. The sector that is typically considered the most sensitive to carbon risk is the energy industry, including oil, gas, coal and power utilities[1], see, e.g. Labatt and White; Labatt and White (2002, 2007).

However, firms that belong to energy-intensive industries such as chemicals, iron, steel, cement, and metallurgy[2] are also expected to be significantly affected by carbon risk. The reason for this is that these basic resources companies typically have a high consumption of fossil fuels (Dell'Aringa & van Ast, 2009).Besides direct *GHG* emissions, the amount of carbon emitted during downstream activities is also relevant. Therefore, we also categorize producers and users of energy-consuming products, such as automobile and transportation[3] as carbon-intensive industries. These companies are very vulnerable, especially to technology risk (e.g. fuel efficiency) as pointed out by Labatt and White (2007) and Goodstein (2011).

[1] Corresponding to the Thomson Reuters industry groups oil & gas, oil & gas related equipment and services, natural gas utilities, coal, electric utilities & ipp and multiline utilities.
[2] Corresponding to the Thomson Reuters industry groups chemicals, metals & mining and construction materials.
[3] Corresponding to the Thomson Reuters industry groups aerospace & defense, automobile & parts, freight & logistics services, passenger transportation and transport infrastructure.

Additionally, we include the sector "Paper and Forest Products" into the list of CO_2-heavy industries. This takes into account that deforestation does not only lead to releases of CO_2 stored in the terrestrial biosphere, but also reduces the ability to absorb emitted greenhouse gases (Intergovernmental Panel on Climate Change, 2015). Hence, the industry also has the potential to worsen global warming and is subject to potential regulatory measures. This leaves us with 15 CO_2-heavy industries that are presented in Table I.

[Insert Table 1 about here]

2.2 Carbon Footprint

By simply using the industry affiliation as a classification scheme, all companies that belong to one of the 15 carbon-intensive industries, will be characterized as having a high exposure to carbon risk. However, in reality not all companies within the same industry will face the same level of carbon risk, as they emit different amounts of GHG.

To achieve a more precise distinction, we therefore follow Hoffmann and Busch (2008) and additionally compute a company's footprint. The carbon footprint is defined as a company's total *GHG* emissions[4] standardized by some proxy of size. In line with Aggarwal and Dow (2011), Balkissoon and Heaps (2014), Saka and Oshika (2014), Kim et al. (2015), Misani and Pogutz (2015), we use the market capitalization as proxy for our ranking:

$$Carbon\ Footprint_M = \frac{Total\ GHG\ Emissions}{Market\ capitalization} \quad (1)$$

Hereby, *Total GHG Emissions* include CO_2-emissions from Scope 1 (emissions from sources directly owned and controlled by the company) and Scope 2 (indirect emissions from the generation of purchased electricity). Emissions from Scope 3, which occur in upstream as well

[4] To overcome the problem of an imperfect time series, we calculate the averages of all normalized CO_2e-emissions from 2008-2015 for each firm. Working with a limited period allows us to create a static sample of CO_2-heavy firms, which can be analyzed over time. Thereby we assume that the average behavior is representative for the whole time period of 2000-2015. We exclude companies without any emission data.

as in downstream activities are not included in this definition, as companies typically have very little influence on these emissions. Besides, reporting on emissions from Scope 3 is optional and available data is therefore not very reliable (Carbon Trust, 2018).

It is important to note that few regulatory bodies require mandatory *GHG* disclosure, while disclosure requirements are typically imposed only on companies with specific features. As a result, the coverage of total CO_2e-emissions data is sparse, especially in the early 2000's. However, Figure 1 shows that lately coverage has increased significantly. In 2015, around 50% of all companies from carbon-intensive industries provide data for total CO_2e-emissions.

To differentiate the best and worst carbon risk stocks, we use a "worst-in-class" approach, i.e. we rank all companies within each carbon-intensive industry based on their carbon footprint (Labatt & White, 2002). Firms with carbon footprint values in the highest 50% of an industry are then classified as 'worst emitters'.[5]

[Insert Figure 1 about here]

2.3 Climate Scoring

Earlier academic studies have mainly neglected the fact that a firm's carbon risk exposure is not solely a question of its quantifiable carbon footprint. If a company wants to reduce its risk, cutting down carbon emissions is only one step. In addition to that, there must be initiatives to develop improvements in dealing with natural resources, see, e.g., Calvello (2010). This is why we also identify firms with high carbon risk exposure through applying a climate related score. This allows us to offer a more comprehensive and future-oriented picture about how a company deals with carbon risk exposure, which also includes qualitative factors. The environmental performance score of a company can be obtained from third-party providers. For this study, we

[5] We acknowledge that one disadvantage of the „worst-in-class" approach is that in sectors with generally low standards, not all companies with high pollution are classified as bad environmental performers, see also Ulshöfer and Bonnet (2009).

decided to use the *Environmental* pillar score (E-score) of the Thomson Reuters ESG Score. The E-Score is based on various indicators for a company that are related to Resource Use, Emissions and Innovation.[6] As indicated in Figure 1, E-score coverage at the beginning of the sample period is rather sparse, while in recent years the score is available for a relatively high share of companies. In a first step, for each company we calculate the average of all reported E-scores from 2008 and 2015. Then, similar to the approach taken to compute the worst carbon footprint based emitters, we classify the lowest 50% in each industry as 'worst E-Score based emitters'.

3 Data

3.1 Firms with high carbon risk exposure

The following section provides summary statistics on the databases used in this study. We obtain data on CO_2e-emissions and E-Scores from the Asset4 ESG database (provided by Thomson Reuters).[7] This database covers the most important shares traded on global stock markets[8] and, therefore, serves as a good proxy for the worldwide investment universe. Data on market capitalization and shares outstanding are sourced from Thomson Reuters Datastream.

Since Asset4 obtains its CO_2-data, inter alia, from the Carbon Disclosure Project, we have to work with voluntarily reported data, which might be unreliable, inconsistent and not validated by a third party, according to Calvello (2009). Furthermore, it also poses the risk of a self-selection bias, where e.g. bad environmental performers consciously do not report emissions in

[6] For further details on the calculation of the Thomson Reuters ESG score in general, the E-score in particular and the Environmental Pillar Categories, see Refinitiv (2019).
[7] Note that in the second half of 2018 the Financial and Risk Business of Thomson Reuters was renamed Refinitiv, after a strategic partnership transaction between Thomson Reuters and private equity funds managed by Blackstone. As a result of the renaming, Refinitiv also now refers to the former Asset4 ESG database as ESG data. Given that the data used in our analysis (as well as the documentation for the data) was sourced before the renaming, in the following we will typically refer to Asset4 and Thomson Reuters.
[8] MSCI Emerging Markets, MSCI World, CAC40, DAX, FTSE250, S&P 500, NASDAQ 100, STOXX 600, ASX 300, SMI and Bovespa.

order to minimize their reputational risks. Nevertheless, the Asset4 database is currently considered as the best available source for environmental, social and governance (ESG) information without viable alternatives (Refinitiv, 2019). Therefore, similar to Aggarwal and Dow (2011), Matsumura et al. (2014), Wang et al. (2014), Saka and Oshika (2014), Misani and Pogutz (2015), who also worked with voluntarily disclosed data, in the following we use information available from Asset4, while acknowledging the potential limitations of this dataset.

In total, we obtain 954 stocks from carbon-intensive industries that have been active for the entire sample period 2000 to 2015. Companies that have entered the stock market later or have been delisted due to mergers or bankruptcy are excluded. By doing so, we create an Asset4 universe in which investors could, theoretically, have been invested in any share at any time of the considered sample period. For the other two definitions of carbon-intensive firms, due to the smaller coverage of available data, we have 312 firms ranked as worst emitters based on their carbon footprint and 469 firms categorized as 'worst E-Score based emitters'.

An overview of the industry and country distribution of these subsamples can be found in Table II. Panel A illustrates that with 254 carbon-intensive companies, or almost one-third of the market capitalization of all carbon-intensive companies, the United States has the highest share of carbon-intensive companies. This is also true for the "worst in class" classification of CO_2-heavy companies based on their climate score, where 147 out of 469 companies are based in the US. Panel B illustrates that the dirtiest industries are typically Oil & Gas, Chemicals, and Metals & Mining. Our summary also shows that the selected 954 carbon-intensive stocks correspond to approximately 26% of the total market capitalization of all Asset4 firms in the sample. Stocks identified as having the worst carbon footprint or the worst climate score correspond to approximately 11% (4%) of the total market capitalization of the Asset4 universe.

[Insert Table II about here]

3.2 Ownership holdings

Our data on ownership structure is sourced from the Thomson Reuters' Global Equity Ownership database. We use year-end holdings from 2000 to 2015. Our focus is on institutional investors (including banks, trusts, insurances, pension and endowment funds and foundations), hedge funds, mutual funds, investment advisors, as well as individuals and government agencies.

Table III shows how the holdings of the companies in our specified Asset4 sample are distributed amongst the different owner groups in the Global Ownership database. Between 2000 and 2015 we observe an average of 12,698 investors with 3,135 distinct firms held in total. The average value held by all investors adds up to 12 trillion USD, which corresponds to a coverage of 42% of the total Asset4 market capitalization. Both Investment Advisors and Hedge Funds hold more than one-sixth of this value and form the largest investor groups, while governments and individuals are the least potent investor types, accounting only for 1.17% of the total market capitalization of the Asset4 universe.

[Insert Table III about here]

4 Results

Our empirical analysis is divided into two major parts. Part I investigates owners and their investment behavior with regard to carbon-intensive stocks. In particular, we examine how much carbon risk exposure portfolios of different owner types contain. We also investigate the fraction of ownership (i.e. the percentage of shares outstanding) for the companies in the portfolios of different owner types. Note that this part of the analysis only considers stocks that are held in the owners' portfolio, whereas in Part II the analysis is augmented to the full

investment universe of all stocks that are potentially available for purchase. Thus, Part II examines how the (CO_2-intensive) stock universe is divided between different owner types. In this part of the analysis, we also investigate how different owner types are invested in 'dirty' stocks, in comparison to their normal investment habits and portfolio allocation.

4.1 On the owners and the stocks in their portfolio

4.1.1 Exposure of "dirty" stocks in investor portfolios

In this section we investigate the carbon risk exposure in portfolios of different owner types. For this purpose, we examine institutionals, hedge funds, individuals, government agencies, investment advisors and mutual funds, and compute different measures of carbon risk exposure.

The carbon risk exposure $CRE_{i,t}$ of investor *i* in *t* is computed as

$$CRE_{i,t} = \frac{\sum_{s \in P_{DS_{i,t}}} value\ held_{i,s,t}}{\sum_{k \in P_{DS_{i,t}} + P_{NDS_{i,t}}} value\ held_{i,k,t}} \qquad (2)$$

where $value\ held_{i,s,t}$ is the value of stock *s* that investor *i* has in her portfolio at time *t*, and $k \in P_{DS_{i,t}}$ describes all 'dirty' stocks DS in portfolio P of investor i at time t. $k \in P_{NDS_{i,t}}$ analogously describes all 'non-dirty' stocks NDS in this portfolio.

We then aggregate all investors within one owner type *j* and compare the exposure of this hypothetical aggregated portfolio. For this purpose, we sum up all corresponding stocks of all investors *i* that belong to owner type *j*. The aggregated carbon risk exposure $aggr.CRE_{j,t}$ of owner type *j* (e.g. all hedge funds) at time *t* is then computed as

$$aggr.CRE_{j,t} = \frac{\sum_{i \in O_j} \sum_{s \in P_{DS_{i,t}}} value\ held_{i,s,t}}{\sum_{i \in O_j} \sum_{s \in P_{DS_{i,t}} + P_{NDS_{i,t}}} value\ held_{i,s,t}} \qquad (3)$$

where $i \in O_j$ contains all investors i that belong to owner type j. Thus, an $aggr.CRE_{j,t}$ value of 30% indicates that all investors of owner type j (e.g. all hedge funds) have 30% of their total money invested in carbon-intensive stocks.

[Insert Table IV about here]

[Insert Figure 2 about here]

Table IV illustrates the development of $aggr.CRE_{j,t}$ for the various investor types over time. Interestingly, the most noteworthy disparity in investment preferences among the different investor types can be observed in government agencies and individual investors. Let us first consider the results that are based on an industry-based definition of the companies, i.e. carbon risk exposure for 'dirty' stocks from CO_2-intensive industries. Findings for this classification are reported in Panel A and illustrated in Figure 2. The results show that the portfolio of government agencies consists of approximately 50% carbon-intensive stocks on average, ranging from 36% in 2000 up to a maximum of 65% in 2011. By contrast, the carbon risk exposure of individual investors is relatively low, with an average of approximately 15%, while other investor types typically hold similar shares of carbon-intensive stocks between 20% and 25%.

Figure 2 also illustrates that these shares are relatively stable over time. Thus, our findings do not suggest a significant change in behavior for any of the investor types between 2000 and 2015 with regard to holding carbon-intensive stocks. Despite the increasing social and political awareness to climate risk, it seems as if these risks are inadequately taken into account or simply ignored by investors when managing their portfolios.

The high investment of government agencies in carbon-intensive stocks is remarkable. The main driver is probably the high occurrence of state-ownership within CO_2-heavy sectors. This

hypothesis is supported by a report of the OECD in 2014, which shows that electricity and gas is one of the most dominant sectors among state-owned listed entities. In Panels B and C, the exposure to carbon-intensive stocks is further disentangled by examining investments into the 'dirtiest' stocks within the carbon-intensive stock category. For this purpose, the worst emitters are defined as the 50% of companies with the highest carbon footprint (Panel B) or the 50% of companies with the worst climate scores (Panel C). While Panel B confirms the relatively high carbon risk exposure of governments, Panel C shows a more homogeneous exposure of the individual owner types.

In order to rule out passive investment behavior and a consequential indifference to carbon risk, in a next step we compute the carbon risk exposure of each investor in excess to the carbon risk exposure of the entire Asset4 market portfolio. We then also examine whether the excess carbon risk exposure for each investor type is significantly different from zero, i.e. we test for each year whether investor type *j* is significantly more (or less) invested in carbon-intensive stocks in comparison to the carbon risk exposure of the entire Asset4 universe. Our measure for excess carbon risk exposure for investor *i* is defined as follows:

$$ex.CRE_{i,t} = CRE_{i,t} - \frac{\sum_{s \in DS_t} market\ cap_{s,t}}{\sum_{k \in DS_t + NDS_t} market\ cap_{k,t}} \qquad (4)$$

Table V shows the average $ex.CRE_{i,t}$ at investor level per owner type and year. The high carbon risk exposure of government agencies is illustrated by significant values between 20 and more than 30 percentage points (pp) in excess to the exposure of the Asset4 'market portfolio'. Interestingly, with the exception of mutual funds, all other types of investors appear to avoid carbon risk, when allocating their portfolios in comparison to the market-inherent exposure. Thus, on average, institutional investors, hedge funds, individuals, and investment advisors all have negative excess carbon risk. Furthermore, while absolute values of the excess carbon risk are typically small (ranging from 1.2 to 3.7 pp), they are all highly significant.

[Insert Table V about here]

4.1.2 Ownerships of stocks in portfolio

Let us now focus on how much ownership different groups of investors have in individual carbon-intensive stocks. Thus, we are interested whether, e.g., hedge funds or governments typically have a high share of ownership in the dirty companies they ae invested in. This will provide us with additional information on the balance of power in shareholder resolutions, which investors could then use, for example, to support a company engagement strategy for meeting climate protection targets.

For this purpose we define for each owner type *j*, the average ownership that this group possesses in a 'dirty' stock in its portfolio.

$$OWNERSHIP\_P\ {}^{shares}_{j,t}(\emptyset) = \frac{1}{n_{DS_{j,t}}} \sum_{s \in P_{DS_{j,t}}} \frac{\sum_{i \in O_j} shares\ held_{i,s,t}}{shares\ outstanding_{s,t}} \quad (5)$$

where $i \in O_j$ contains all investors *i* that belong to owner type *j*, and $n_{DS_{j,t}}$ is the number of stocks held by owner type *j* at time *t.* Therefore, an $OWNERSHIP\_P\ {}^{shares}_{j,t}(\emptyset)$ of 25% means that owner type *j* (e.g. all hedge funds) owns on average one quarter of the shares outstanding of each 'dirty' stock in their portfolio *P*.

[Insert Table VI about here]

Table VI illustrates the average ownership of a 'dirty' stock in the portfolio of the respective owner types. While institutional and individual investors as well as mutual funds play a relatively minor role in terms of the ownership distribution, the significance of government agencies is evident once again: on average, government agencies hold around 27% of outstanding shares of a carbon-intensive stock in their portfolio. This again might indicate a high occurrence of state-ownership within CO_2-intensive sectors. Interestingly, hedge funds and investment advisors are

also relevant shareholder groups with an average ownership of 13% and 18% respectively. Overall, our results suggest that due to their high share of ownership, in particular these three investor types might be able to influence environmental awareness and behavior in the carbon-intensive companies they are invested in.

4.2 About the owners and the full investment universe

So far our analysis only considers stocks that are held in the owners' portfolio. However, it does not take into account that some of the carbon-intensive stocks might be completely ignored by the different investor types. To illustrate this difference, imagine a universe with 100 CO_2-intensive stocks. If hedge funds only invest in one of these companies (e.g. with ownership = 100%), our analysis in part I correctly detects that they possess 100% of the 'dirty' stocks in their portfolio. However, it does not take into account that there are 99 further carbon-intensive companies in which their share is 0%. To draw inferences about ownership of different investor types in the CO_2-intensive stock universe, in the following we consider the full investment universe of all stocks potentially available for purchase. Such an analysis allows us to answer the following questions: How is the whole (carbon-intensive) stock universe divided between the different owner types? How are the different owner types invested in the 'dirty' stocks universe in comparison to their usual investment habits and portfolio allocations?

For this analysis, we rely on the $OWNERSHIP_{j,t}(aggr.)$ measure that is developed in the previous section. Clearly, the main difference to the analysis previously conducted is in the denominator: we no longer consider only market capitalization of CO_2-intensive stocks in the portfolios of the different owners ($s \in P_{DS_{j,t}}$), but the whole investment universe of all carbon intensive stocks. Thus, we consider all 'dirty' stocks ($s \in DS_t$) that could have been bought by the different investor types. Therefore, we define a measure of aggregate ownership in dirty stocks,

$$OWNERSHIP_{j,t}^{value}(aggr.) = \frac{\sum_{i \in O_j} \sum_{s \in P_{DS_{i,t}}} valueheld_{i,s,t}}{\sum_{s \in DS_t} marketcap_{s,t}} \quad (6)$$

where $s \in DS_t$ contains all stocks in the carbon-intensive stocks available in the Asset4 universe at time *t*.

[Insert Figure 3 about here]

Figure 3 shows how the ownership of carbon-intensive stocks is distributed among the different types of investors. It illustrates that investment advisors and hedge funds are the strongest owner groups, each holding around 13% to 15% of the market capitalization of all carbon-intensive stocks in our sample. In contrast to the previous analysis, government agencies play a subordinate role from this perspective: only 2% of the market capitalization of all carbon-intensive companies are owned by governments. Overall, we see their role as a carbon risk taker mainly stemming from state-ownership of selected CO_2-intensive firms. In total, Figure 3 reveals that hedge funds and investment advisors hold the highest proportion of the carbon risk bomb. This might not only be interesting for clients of these investors, but also for policy makers, who are thinking of controlling the sponsors of carbon-intensive companies. It also highlights the relevance of some of these investor groups' voluntary commitments[9] to tackle climate change by decarbonizing their portfolios.

One might argue that different owner types have different amounts of money to invest. For this reason it is self-evident that owner types with more assets under management are generally able to have a higher percentage of ownership in companies. Therefore, solely relying on aggregated measures of ownership might yield misleading conclusion. To draw conclusions on the different owners' investment preferences in carbon-intensive stocks, we now conduct an analysis that

[9] For example the 'The Global Investor Statement on Climate Change', which was facilitated by the UNEP Finance Initiative.

relates investor type ownership of one individual stock to their average ownership in other stocks. Let

$$OWNERSHIP_{j,s,t}^{value} = \frac{\sum_{i \in o_j} value\ held_{i,s,t}}{marketcap_{s,t}} \qquad (7)$$

denote the ownership of investor type *j* of a specific stock *s* at time *t*, i.e. as the sum of value held of stock *s* by all investors *i* of group *j* divided by the market capitalization of stock *s* at time *t*. In order to evaluate how much this single investment differs from the owner group's *j* usual investment behavior, we adjust the ownership in stock *s* of owner type *j* by the owner type's average ownership in all other stocks, which yields

$$\Delta OWNERSHIP_{j,s,t} = OWNERSHIP_{j,s,t}^{value} - \frac{1}{n_{DS_t+NDS_t}} \sum_{s \in DS_t+NDS_t} OWNERSHIP_{j,s,t}^{value} \qquad (8)$$

Thus, a value of 1% for the variable $\Delta OWNERSHIP_{j,s,t}$ indicates that on average investors of type *j* (e.g. hedge funds) holds 1 pp more of this particular company *s* than they hold on average in other carbon-intensive and non-carbon-intensive companies.

Panel A in Table VII focuses on the ownership preference in carbon-intensive companies. It displays how the average $\Delta OWNERSHIP$ for every type of investor for all carbon-intensive stocks of the Asset4 universe has developed over time. It can be observed that governments are the only owner group with a constantly positive value of $\Delta OWNERSHIP$. This indicates that on average governments have a higher share of ownership in a specific 'dirty' company than the average ownership in all other Asset4 companies. This inferred preference for carbon-intensive firms is in line with our findings from Part I of our empirical analysis. All remaining investor types have negative or insignificant values of $\Delta OWNERSHIP$, which means that they typically underweight CO_2-intensive stocks in comparison to their usual investment behavior.

[Insert Table VII about here]

Analogous to this, Panel B shows that governments invest less in non-carbon-intensive companies while all other types of investors seem to either favor non-carbon-intensive stocks or have no significant preference in this respect.

5 Conclusion

We provide one of the first studies to examine the exposure of various types of investors to carbon-intensive stocks, using a large universe of firms. In particular, we combine different metrics to classify carbon-intensive stocks with Thomson Reuters' Global Equity Ownership database, which provides year-end holdings for these stocks over a sample period from 2000 to 2015. The applied approach allows us to thoroughly examine the ownership structure of carbon-intensive stocks for various owner types such as institutional investors, hedge funds, individuals, investment advisors, mutual funds or government agencies.

The conducted analysis allows us to answer important questions related to carbon risk and ownership structure. We define three different categories of carbon-intensive stocks that help to identify companies that are particularly exposed to carbon risk, i.e. to possible regulatory changes with regard to *GHG* emissions. We argue that auditors, investors and financial decision-makers have a great interest in understanding which firms could be particularly affected by new policies restricting carbon emissions and the increasing need for a full disclosure of resulting carbon risk. This interest may be based on the possible detrimental effects of such policies on the financial performance of these companies or may be related to ethical issues, i.e. demanding better environmental and climate related management practices in these firms.

Moreover, we are the first to work with an extensive dataset of ownership structures in order to analyze investor behavior related to carbon-intensive stocks. In particular, we examine portfolios of different owner types, with regard to their investment in the classified high-

polluting firms. Interestingly, we find that it is actually government agencies who have the highest exposure to carbon risk, with approximately 50% of their portfolios invested in carbon-intensive stocks. Comparable numbers for all other investor types are significantly lower and on average lie between 15% and 25% of their total investments during the sample period. Importantly, we do not find evidence that suggests a significant change in investor behavior with regard to holding carbon-intensive stocks in their portfolio during the sample period. This might suggest that avoiding high-polluting stocks or identifying exposure to carbon risk does not play a major role yet in investment decisions.

Another area of interest is the percentage of the shares outstanding of high-polluting firms held by the different investor groups. The results show that governments typically hold around 27% of a carbon-intensive stock in their portfolio, investment advisors hold 17%, hedge funds 13%, while all other investor types hold a significantly lower share. In this context, it is also interesting to investigate how the whole CO_2-intensive stock universe is divided between different owner types. We find that mainly hedge funds and investment advisors form the biggest investor groups, which have an ownership of about 13% each. Both aspects help to understand how influential the different owner types are for the carbon-intensive sector overall as well as for specific stocks that have a high share of government agencies as investors. We argue that in particular governments, hedge funds and investment advisors could possibly drive organizational change, environmental awareness towards more climate-oriented goals in carbon-intensive companies.

Moreover, we provide more detailed information on the preferences of each owner type, by examining how they are invested in carbon-intensive stocks in comparison to their overall investment behavior. Our findings suggest that hedge funds, individuals and investment advisors own statistically significant less carbon-intensive stocks in comparison to their average ownership. At the same time, government agencies have significantly more ownership in

carbon-intensive stocks. These results are at least somehow surprising, given that it is typically government claiming to expedite the transition to a low-carbon and climate resilient economy. We believe that the information provided in this study can help policy-makers in tailoring incentives for each investor type to facilitate the goal of reducing emissions. Based on our results, the reduction of emissions can be pushed forward by either encouraging investors to de-invest in carbon-intensive firms or, particularly in case of government agencies, by executing voting rights to influence the emission levels of carbon-intensive firms

Our results also suggest several directions for future research. One of the possible directions is to explore the importance of different investor types assign to carbon risk exposure and how much it influences their investment decisions in real life. Given that it is typically government agencies holding the highest shares in carbon-intensive firms, it might, furthermore, be worthwhile to investigate the relationship between shareholder activism and carbon-intensive companies, especially in the context of state-ownership.

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Figures and Tables

Figure 1: Available CO_2e-emission reportings and E-scores

This figure presents the number (left y-axis) and the percentage (right y-axis) of firms from CO_2-intensive industries with available CO_2e-emission reportings or E-scores. The observed period are the years from 2000 to 2015.

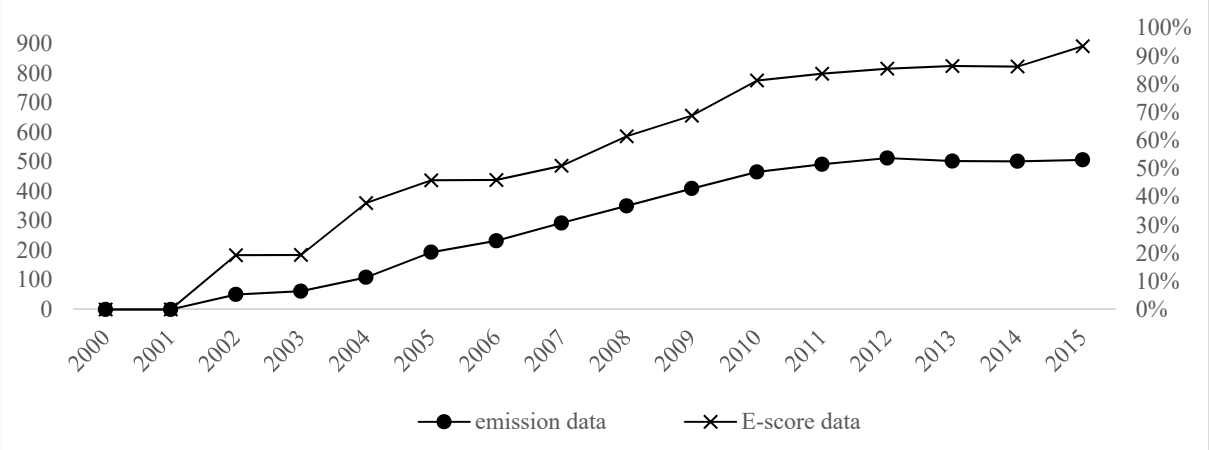

Figure 2: Aggregated Carbon risk exposure in different investor portfolios

The following graphs show the carbon risk exposure for 'dirty' stocks from CO_2-intensive industries as a percentage of all Asset4 holdings held by each one of the following investor types: Institutionals, Hedge Funds, Individuals, Government Agencies, Investment Advisors and Mutual Funds.

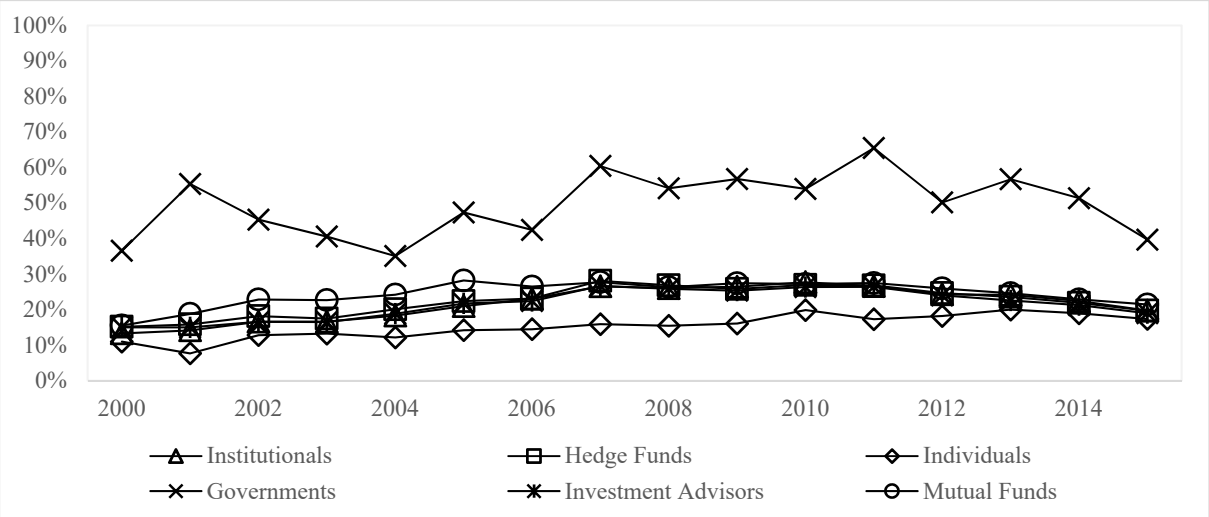

Figure 3: Carbon stock ownership of the different investor types - full investment universe

The following graphs show how the full carbon stock universe is split between different owner groups. They show the ownership distribution of carbon-intensive stocks according to their affiliation to 15 CO_2-intensive industries. The graphs present the aggregated ownership of each owner group measured in value held of the market capitalization $OWNERSHIP_{j,t}^{value}(aggr.)$.

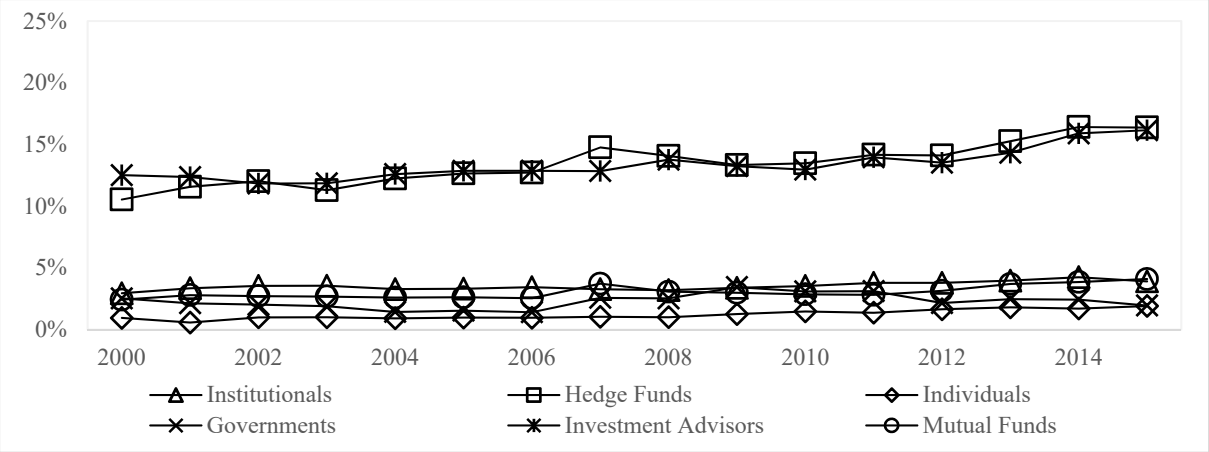

Table I: CO2-intensive industries

This table includes the 14 industries from three categories, which are most sensitive to carbon risk. In addition to the sectors provided, we also include the "Paper & Forest Products" industry into the list of CO_2-intensive industries. Every company in Asset4 that belongs to one of these 15 industries is categorized as carbon-intensive in our analysis.

Energy industry	**Energy-intensive industry**	**Energy-consuming products**
Coal	Chemicals	Aerospace and Defense
Electric Utilities and IPPs	Construction Materials	Automobile and Parts
Natural Gas Utilities	Metals and Mining	Freight and Logistics Services
Multiline Utilities		Passenger Transportation Services
Oil and Gas		Transport Infrastructure
Oil and Gas - Equipment and Services		
Paper and Forest Products		

Table II: Number of firms in Asset4 categorized as carbon-intensive stocks

Panels A and B include the number of 'dirty' stocks and their proportion of the market capitalization of all 'dirty' stocks, which are covered in the subsample after selecting 954 Asset4 companies that belong to the 15 most CO2-sensitive industries and after applying the "worst-in-class" approach for carbon and climate scoring. Panel A shows where the remaining Asset4 firms have their headquaters. Panel B shows how many of these firms belong to each of the defined CO2-intensive industries. Furthermore, it includes the equivalent proportion of the total Asset4 market capitalization.

Panel A: Distribution by country

	Industry Affiliation		Worst Carbon Footprint		Worst Climate Score	
Country	# firms	% market cap. of all dirty stocks	# firms	% market cap. of all dirty stocks	# firms	% market cap. of all dirty stocks
Australia	82	2.88%	13	1.64%	53	1.11%
Brazil	6	1.50%	1	1.66%	1	0.77%
Canada	101	5.25%	21	4.41%	63	7.79%
Chile	9	0.65%	3	0.24%	6	1.83%
China	34	2.05%	5	0.50%	24	4.82%
European Union	166	28.57%	72	39.16%	42	8.81%
India	27	2.04%	12	2.47%	12	2.02%
Indonesia	8	0.36%	4	0.56%	4	1.38%
Japan	108	12.07%	58	10.40%	36	11.52%
Korea	23	1.68%	11	2.12%	9	2.03%
Malaysia	12	0.61%	7	0.86%	8	2.51%
Mexico	6	0.45%	1	0.38%	2	0.18%
New Zealand	11	0.14%	1	0.03%	9	0.66%
Norway	9	0.40%	3	0.61%	4	0.47%
Others	14	1.53%	2	2.03%	10	2.00%
Russia	4	2.35%	1	2.97%	0	0.00%
Singapore	8	0.47%	1	0.36%	2	0.58%
South Africa	24	1.17%	16	2.31%	8	0.53%
Switzerland	11	1.26%	1	0.52%	4	1.52%
Taiwan	25	0.99%	12	1.32%	18	4.55%
Thailand	6	0.24%	2	0.11%	2	0.17%
Turkey	6	0.21%	1	0.14%	5	0.90%
United States	254	33.14%	64	25.20%	147	43.85%
Total	954	100.00%	312	100.00%	469	100.00%

Panel B: Distribution by industry

	Industry Affiliation		Worst Carbon Footprint		Worst Climate Score	
Industry	# firms	% market cap. of all dirty stocks	# firms	% market cap. of all dirty stocks	# firms	% market cap. of all dirty stocks
Aerospace & Defense	45	5.97%	14	5.93%	21	5.48%
Automobiles & Auto Parts	95	12.11%	34	8.94%	45	11.33%
Chemicals	113	8.26%	41	8.83%	55	16.13%
Coal	13	0.28%	2	0.05%	7	0.85%
Construction Materials	33	1.96%	13	2.52%	17	3.92%
Electrical Utilities & IPPs	80	10.72%	34	11.19%	40	15.39%
Freight & Logistics Svcs.	61	4.81%	16	5.19%	30	4.92%
Metals & Mining	176	10.85%	50	12.23%	86	6.45%
Multiline Utilities	27	2.51%	11	2.77%	14	2.70%
Natural Gas Utilities	26	1.43%	6	1.13%	13	2.16%
Oil & Gas	131	31.49%	44	33.57%	65	13.02%
Oil & Gas Equipment and Svcs.	60	4.45%	15	3.65%	30	6.72%
Paper & Forest Products	18	0.65%	6	0.66%	8	0.99%
Passenger Transportation Svcs.	48	3.35%	17	2.56%	24	7.90%
Transport Infrastructure	28	1.18%	9	0.77%	14	2.04%
Total	954	100.00%	312	100.00%	469	100.00%
Aggregated market cap. (bn $)	7,304		3,121		1,222	
% of total Asset4 market cap.	26.00%		10.97%		4.29%	

Table III: Comparison of different investor types

This table shows the number of investors, the number of companies held, the value held and the corresponding percentage of the total market capitalization of the Asset4 universe. The statistics are presented as an average based on the year-end data between 2000 and 2015 for each owner type.

	Institutionals	**Hedge Funds**	**Individuals**	**Governments**	**Investment Advisors**	**Mutual Funds**	**All Investors**
# of owners	594	1,464	7,309	42	1,923	1,366	12,698
# of held firms	2,786	3,053	1,092	91	2,232	3,031	3,135
Value held (bn $)	1,177	4,423	577	336	4,522	928	11,963
% of Asset4 market cap.	4.16%	15.27%	1.97%	1.17%	15.81%	3.15%	41.52%

Table IV: Aggregated Carbon risk exposure in different investor portfolios

The table reports the value of Asset4 firms from CO_2-intensive industries as a percentage of all Asset4 holdings held by each one of the following investor types: Institutionals, Hedge Funds, Individuals, Government Agencies, Investment Advisors and Mutual Funds. Results in each panel vary due to the different categories of CO_2-intensive stocks. Panel A shows the carbon risk exposure for 'dirty' stocks from CO_2-intensive industries. Panel B represents the results for the worst emitters according to the ranking of their carbon footprint. Finally, Panel C includes the exposures in stocks with the worst ranking in climate scoring.

Panel A: Stocks from CO2-intensive industries

Year	**Institutionals**	**Hedge Funds**	**Individuals**	**Governments**	**Investment Advisors**	**Mutual Funds**	**All Investors**
2000	13.27%	15.13%	10.97%	36.53%	14.95%	15.48%	15.43%
2001	14.14%	15.81%	7.64%	55.36%	14.97%	18.77%	15.94%
2002	16.56%	18.14%	12.78%	45.29%	16.55%	22.83%	18.07%
2003	16.59%	17.46%	13.21%	40.55%	16.47%	22.66%	17.72%
2004	18.30%	20.07%	12.13%	35.07%	18.82%	24.19%	19.65%
2005	20.97%	22.36%	14.18%	47.33%	21.71%	28.18%	22.48%
2006	23.02%	23.10%	14.45%	42.41%	22.39%	26.46%	23.08%
2007	26.52%	28.08%	15.87%	60.43%	26.65%	27.71%	27.83%
2008	26.02%	26.83%	15.42%	54.15%	25.85%	26.30%	26.73%
2009	26.43%	25.80%	16.04%	56.75%	25.32%	27.42%	26.59%
2010	27.72%	26.91%	19.85%	53.95%	26.33%	27.19%	27.55%
2011	26.58%	26.78%	17.28%	65.49%	26.39%	27.45%	27.43%
2012	24.29%	24.61%	18.18%	50.16%	23.98%	25.94%	24.78%
2013	24.14%	23.56%	19.98%	56.69%	22.55%	24.59%	23.98%
2014	22.40%	21.87%	18.93%	51.34%	21.23%	22.87%	22.33%
2015	19.71%	19.69%	17.35%	39.67%	18.96%	21.42%	19.88%
mean	21.67%	22.26%	15.27%	49.45%	21.44%	24.34%	22.47%
median	22.71%	22.73%	15.64%	50.75%	22.05%	25.26%	22.78%
std. deviation	4.58%	4.04%	3.29%	8.60%	4.06%	3.44%	4.12%
min	13.27%	15.13%	7.64%	35.07%	14.95%	15.48%	15.43%
max	27.72%	28.08%	19.98%	65.49%	26.65%	28.18%	27.83%

Table IV continued: Aggregated Carbon risk exposure in different investor portfolios

Panel B: Stocks with worst carbon footprint ranking

Year	Institutionals	Hedge Funds	Individuals	Governments	Investment Advisors	Mutual Funds	All Investors
2000	5.15%	6.58%	4.52%	20.53%	6.01%	6.68%	6.58%
2001	5.34%	6.88%	2.86%	33.96%	5.94%	8.38%	6.79%
2002	6.39%	7.80%	2.45%	29.12%	6.53%	9.69%	7.55%
2003	6.06%	7.18%	3.26%	27.86%	6.42%	9.78%	7.29%
2004	6.49%	8.25%	2.26%	18.94%	7.31%	10.53%	7.82%
2005	7.79%	9.17%	2.91%	29.92%	8.75%	12.04%	9.20%
2006	8.33%	9.16%	1.98%	17.57%	8.68%	12.43%	8.97%
2007	9.81%	11.12%	3.42%	26.20%	10.13%	12.81%	10.92%
2008	9.32%	9.79%	2.75%	26.01%	9.08%	11.28%	9.82%
2009	10.17%	9.52%	3.29%	30.39%	9.18%	11.72%	10.17%
2010	10.26%	9.45%	4.77%	27.28%	9.69%	11.66%	10.29%
2011	9.96%	9.13%	3.48%	37.62%	9.09%	11.38%	10.00%
2012	9.41%	8.62%	3.65%	29.75%	8.15%	10.80%	8.99%
2013	9.12%	8.15%	3.95%	31.08%	7.75%	10.00%	8.61%
2014	8.81%	8.08%	4.23%	23.54%	7.97%	8.55%	8.34%
2015	7.73%	7.22%	4.00%	19.48%	7.21%	7.50%	7.40%
mean	8.13%	8.51%	3.36%	26.83%	7.99%	10.33%	8.67%
median	8.57%	8.43%	3.36%	27.57%	8.06%	10.66%	8.79%
std. deviation	1.70%	1.18%	0.78%	5.46%	1.28%	1.74%	1.30%
min	5.15%	6.58%	1.98%	17.57%	5.94%	6.68%	6.58%
max	10.26%	11.12%	4.77%	37.62%	10.13%	12.81%	10.92%

Panel C: Stocks with worst Escore ranking

Year	Institutionals	Hedge Funds	Individuals	Governments	Investment Advisors	Mutual Funds	All Investors
2000	2.46%	2.60%	3.13%	0.81%	2.65%	1.00%	2.45%
2001	2.41%	2.79%	2.72%	0.15%	2.62%	1.23%	2.52%
2002	2.45%	3.00%	3.65%	1.51%	2.84%	1.89%	2.79%
2003	2.44%	3.05%	5.26%	0.79%	3.02%	2.10%	2.94%
2004	3.02%	3.63%	3.70%	1.44%	3.71%	2.30%	3.46%
2005	3.24%	4.23%	4.65%	1.66%	4.00%	2.45%	3.89%
2006	3.29%	4.16%	4.15%	7.42%	3.97%	2.53%	3.96%
2007	4.36%	5.12%	5.77%	6.80%	5.12%	3.24%	4.95%
2008	4.13%	4.62%	4.60%	7.04%	4.66%	2.94%	4.53%
2009	4.41%	4.91%	5.35%	5.41%	5.03%	3.39%	4.84%
2010	4.38%	5.82%	6.80%	4.69%	5.39%	4.57%	5.44%
2011	4.43%	6.11%	5.89%	5.77%	5.52%	4.76%	5.61%
2012	4.44%	5.85%	5.38%	6.50%	5.49%	4.46%	5.46%
2013	4.26%	5.66%	5.07%	4.51%	5.48%	4.09%	5.27%
2014	4.05%	5.34%	4.88%	5.16%	5.12%	4.41%	5.03%
2015	3.52%	4.56%	4.47%	4.20%	4.26%	3.87%	4.28%
mean	3.58%	4.47%	4.72%	3.99%	4.31%	3.08%	4.21%
median	3.79%	4.59%	4.77%	4.60%	4.46%	3.09%	4.41%
std. deviation	0.80%	1.13%	1.04%	2.45%	1.04%	1.17%	1.07%
min	2.41%	2.60%	2.72%	0.15%	2.62%	1.00%	2.45%
max	4.44%	6.11%	6.80%	7.42%	5.52%	4.76%	5.61%

Table V: Excess Carbon Risk Exposure in different investor portfolios

The following table shows the average carbon risk exposure for 'dirty' stocks from CO_2-intensive industries of all investors within each investor type. ***, **, * denote significance at the 1%, 5%, and 10% levels resulting from a two-sided t-test with the null hypothesis $\overline{ex.CRE_{\iota,t}} = 0$.

Year	Institutionals	Hedge Funds	Individuals	Governments	Investment Advisors	Mutual Funds	All Investors
2000	-1.56*	0.09	-2.42***	25.67***	-2.04***	1.61***	-1.17***
2001	-2.49***	-1.65**	-0.34	34.78***	-3.87***	1.28**	-0.98***
2002	-1.04	-0.42	-3.47***	26.34***	-4.71***	3.15***	-2.03***
2003	-0.36	-0.82	-1.96***	31.32***	-3.50***	3.27***	-1.25***
2004	-2.82***	0.07	-3.70***	31.16***	-3.15***	2.11***	-2.28***
2005	-2.15**	0.88	-4.69***	23.48***	-4.65***	1.10*	-3.16***
2006	-4.16***	-1.03*	-4.52***	26.72***	-5.55***	1.19**	-3.50***
2007	-4.32***	-1.72***	-8.08***	24.94***	-4.95***	0.10	-5.59***
2008	-2.22**	-2.01***	-6.61***	21.01***	-4.80***	0.20	-4.91***
2009	-2.23**	-3.66***	-7.39***	20.29***	-5.70***	0.79	-5.70***
2010	-2.70***	-1.40**	-6.76***	20.06***	-5.68***	-0.83	-5.19***
2011	-1.35	-1.65***	-6.14***	19.90***	-3.62***	1.22**	-4.26***
2012	0.55	-2.37***	-1.81***	23.28***	-3.00***	1.01**	-1.57***
2013	2.08*	-0.38	-0.11	28.06***	-2.22***	0.76*	-0.19
2014	4.62***	-0.49	3.71***	31.45***	-1.63***	1.61***	2.28***
2015	4.72***	-1.41***	1.47***	29.80***	-1.91***	2.51***	0.98***
All years	-0.98***	-1.20***	-3.26***	25.58***	-3.70***	1.27***	-2.40***

Table VI: Carbon stock ownership of the different investor types

The following tables illustrate the fraction of carbon-intensive stocks that is owned by the different types of investors. Carbon-intensive stocks that do not occur in the investors' portfolios are not considered. The tables present the average ownership measured in value held of the market capitalization $OWNERSHIP\_P_{j,t}^{shares}(\emptyset)$ through time. The results in each panel vary due to the different categories of CO_2-intensive stocks. Panel A shows the ownership share for stocks from CO_2-intensive industries. Panel B represents the results for the worst emitters according to the ranking of their carbon footprint. Finally, Panel C includes the average ownership in a stock with the worst ranking in climate scoring.

Panel A: Stocks from CO2-intensive industries

Year	Institutionals	Hedge Funds	Individuals	Governments	Investment Advisors	Mutual Funds	All Investors
2000	3.20%	9.29%	9.29%	25.25%	12.14%	2.21%	20.54%
2001	3.04%	9.77%	9.26%	27.90%	16.80%	2.50%	21.17%
2002	3.37%	10.64%	9.42%	21.94%	15.79%	2.61%	23.03%
2003	3.34%	10.98%	8.79%	21.24%	16.05%	2.72%	24.90%
2004	3.00%	12.06%	7.64%	19.84%	16.73%	2.48%	25.91%
2005	3.05%	12.62%	8.21%	24.25%	17.24%	2.42%	27.86%
2006	3.29%	13.45%	7.27%	22.81%	17.71%	2.52%	29.89%
2007	3.14%	14.90%	7.08%	27.35%	16.64%	3.88%	33.39%
2008	2.75%	13.30%	6.26%	29.36%	19.07%	3.18%	31.63%
2009	3.10%	13.28%	6.53%	30.87%	18.58%	2.97%	32.18%
2010	3.04%	13.72%	6.59%	33.31%	17.58%	3.31%	32.92%
2011	3.30%	13.99%	6.12%	32.22%	18.46%	3.30%	33.38%
2012	3.22%	14.16%	6.25%	29.34%	18.52%	3.44%	33.84%
2013	3.14%	14.43%	6.13%	29.51%	19.44%	4.13%	34.93%
2014	3.42%	15.37%	5.26%	32.12%	20.24%	4.62%	36.74%
2015	3.28%	15.55%	5.50%	32.47%	21.47%	4.74%	36.95%
mean	3.17%	12.97%	7.22%	27.49%	17.65%	3.19%	29.95%
median	3.17%	13.37%	6.84%	28.62%	17.65%	3.07%	31.90%
std. deviation	0.17%	1.87%	1.34%	4.26%	2.06%	0.77%	5.21%
min	2.75%	9.29%	5.26%	19.84%	12.14%	2.21%	20.54%
max	3.42%	15.55%	9.42%	33.31%	21.47%	4.74%	36.95%

Panel B: Stocks with worst carbon footprint ranking

Year	Institutionals	Hedge Funds	Individuals	Governments	Investment Advisors	Mutual Funds	All Investors
2000	2.89%	7.37%	3.91%	24.37%	9.23%	2.27%	17.40%
2001	2.66%	7.50%	5.60%	18.31%	14.42%	2.70%	17.54%
2002	3.07%	8.10%	5.48%	16.06%	12.21%	2.60%	18.36%
2003	2.87%	8.36%	5.02%	11.65%	12.58%	2.72%	19.59%
2004	2.44%	9.14%	3.51%	10.37%	13.25%	2.67%	20.44%
2005	2.89%	9.69%	4.80%	13.94%	13.83%	2.47%	22.39%
2006	3.11%	10.40%	3.10%	10.92%	15.16%	2.62%	23.41%
2007	2.84%	12.10%	3.70%	18.86%	13.56%	4.15%	27.17%
2008	2.51%	10.76%	3.61%	18.13%	15.82%	3.31%	25.27%
2009	3.09%	10.83%	4.35%	24.45%	15.30%	3.13%	26.51%
2010	2.86%	10.85%	4.64%	24.87%	15.40%	3.46%	26.70%
2011	3.33%	11.02%	3.94%	24.44%	15.60%	3.36%	26.41%
2012	3.55%	11.60%	4.72%	25.66%	15.68%	3.63%	27.98%
2013	3.31%	12.07%	4.69%	26.21%	16.19%	4.16%	28.67%
2014	3.66%	12.63%	4.70%	25.89%	17.74%	4.47%	30.41%
2015	3.32%	12.91%	4.13%	28.23%	19.04%	4.45%	30.51%
mean	3.02%	10.33%	4.37%	20.15%	14.69%	3.26%	24.30%
median	2.98%	10.80%	4.49%	21.62%	15.23%	3.22%	25.84%
std. deviation	0.34%	1.74%	0.69%	5.91%	2.23%	0.71%	4.35%
min	2.44%	7.37%	3.10%	10.37%	9.23%	2.27%	17.40%
max	3.66%	12.91%	5.60%	28.23%	19.04%	4.47%	30.51%

Table VI continued: Carbon stock ownership of the different investor types

Panel C: Stocks with worst Escore ranking

Year	Institutionals	Hedge Funds	Individuals	Governments	Investment Advisors	Mutual Funds	All Investors
2000	3.85%	10.37%	10.35%	15.47%	13.45%	1.80%	19.46%
2001	3.65%	10.97%	11.04%	8.17%	18.86%	1.97%	20.48%
2002	3.59%	11.97%	11.41%	12.05%	18.65%	2.29%	22.77%
2003	3.60%	12.24%	11.70%	15.87%	19.22%	2.57%	25.22%
2004	3.39%	13.41%	9.83%	16.99%	20.18%	2.12%	26.19%
2005	3.14%	13.97%	10.02%	32.25%	20.17%	2.18%	28.14%
2006	3.19%	14.77%	9.01%	37.07%	20.49%	2.37%	30.44%
2007	3.21%	15.48%	9.28%	45.61%	19.15%	3.52%	33.70%
2008	2.82%	13.89%	7.48%	42.12%	22.55%	2.87%	32.08%
2009	3.12%	13.97%	8.24%	39.12%	21.75%	2.51%	32.85%
2010	2.82%	14.96%	7.99%	36.55%	20.07%	3.07%	34.30%
2011	3.18%	15.27%	7.71%	42.95%	21.56%	3.05%	34.97%
2012	2.92%	15.50%	7.04%	33.82%	21.22%	3.13%	35.19%
2013	2.83%	15.53%	6.79%	33.64%	22.59%	3.85%	36.16%
2014	3.08%	16.59%	5.40%	37.58%	22.42%	4.43%	37.51%
2015	3.00%	16.56%	6.04%	42.21%	23.67%	4.62%	37.55%
mean	3.21%	14.09%	8.71%	30.72%	20.38%	2.90%	30.44%
median	3.16%	14.37%	8.62%	35.18%	20.34%	2.72%	32.46%
std. deviation	0.31%	1.82%	1.86%	12.10%	2.30%	0.82%	5.81%
min	2.82%	10.37%	5.40%	8.17%	13.45%	1.80%	19.46%
max	3.85%	16.59%	11.70%	45.61%	23.67%	4.62%	37.55%

Table VII: Delta ownership

The following table shows the average $\Delta OWNERSHIP_{j,s,t}$ for stocks allocated to CO_2-intensive industries (Panel A) and to non CO_2-intensive industries (Panel B) of each owner type and year. ***, **, * denote significance at the 1%, 5%, and 10% levels resulting from a two-sided t-test with the null hypothesis $\overline{\Delta OWNERSHIP_{j,s,t}} = 0$.

Panel A: Delta ownership of carbon-intensive stocks

Year	Institutionals	Hedge Funds	Individuals	Governments	Investment Advisors	Mutual Funds	All Investors
2000	-0.38***	-1.66***	-0.84***	0.54**	-1.34***	-0.19*	-0.65***
2001	-0.48***	-1.80***	-1.17***	0.54**	-1.93***	-0.10	-0.82***
2002	-0.33**	-1.98***	-0.68***	0.51**	-2.04***	-0.02	-0.76***
2003	-0.43***	-1.98***	-0.81***	0.48**	-2.14***	0.13	-0.79***
2004	-0.41***	-1.7***	-1.01***	0.49**	-1.78***	-0.01	-0.74***
2005	-0.47***	-2.11***	-0.75***	0.47**	-2.18***	-0.01	-0.84***
2006	-0.39***	-2.21***	-0.67***	0.41**	-2.18***	0.04	-0.83***
2007	-0.31**	-2.1***	-0.79***	0.69***	-2.35***	0.15	-0.78***
2008	-0.33***	-2.19***	-0.89***	0.73***	-2.33***	0.09	-0.82***
2009	-0.25**	-2.21***	-0.70***	0.82***	-2.48***	0.12	-0.78***
2010	-0.21*	-2.06***	-0.49*	0.86***	-2.58***	0.19	-0.71***
2011	-0.17	-1.81***	-0.70***	0.87***	-2.39***	0.24*	-0.66***
2012	-0.24*	-2.1***	-0.74***	0.7***	-2.66***	0.19	-0.81***
2013	-0.25**	-2.25***	-0.57**	0.83***	-2.67***	0.11	-0.8***
2014	-0.18	-2.02***	-0.63**	0.83***	-2.59***	0.09	-0.75***
2015	-0.21*	-2.09***	-0.40	0.72***	-2.46***	0.01	-0.74***
All years	-0.31***	-2.02***	-0.74***	0.66***	-2.26***	0.06**	-0.77***

Panel B: Delta ownership of non carbon-intensive stocks

Year	Institutionals	Hedge Funds	Individuals	Governments	Investment Advisors	Mutual Funds	All Investors
2000	0.14	0.63**	0.32*	-0.21***	0.51*	0.07	0.25***
2001	0.18*	0.68**	0.44**	-0.20***	0.73**	0.04	0.31***
2002	0.12	0.75***	0.26	-0.19***	0.77***	0.01	0.29***
2003	0.16*	0.75**	0.31	-0.18**	0.81***	-0.05	0.30***
2004	0.16*	0.65**	0.38**	-0.19**	0.68**	0.00	0.28***
2005	0.18**	0.80**	0.28	-0.18**	0.83***	0.00	0.32***
2006	0.15	0.84**	0.26	-0.16**	0.83**	-0.01	0.32***
2007	0.12	0.80**	0.3	-0.26***	0.89***	-0.06	0.30***
2008	0.13	0.83***	0.34*	-0.28***	0.88**	-0.03	0.31***
2009	0.10	0.84***	0.27	-0.31***	0.94***	-0.04	0.30***
2010	0.08	0.78**	0.18	-0.33***	0.98***	-0.07	0.27***
2011	0.07	0.69**	0.27	-0.33***	0.91***	-0.09	0.25***
2012	0.09	0.8**	0.28	-0.26***	1.01***	-0.07	0.31***
2013	0.09	0.86***	0.21	-0.31***	1.01***	-0.04	0.30***
2014	0.07	0.77**	0.24	-0.32***	0.98***	-0.03	0.28***
2015	0.08	0.79**	0.15	-0.27***	0.93**	-0.01	0.28***
All years	0.12***	0.77***	0.28***	-0.25***	0.86***	-0.02	0.29***