# Carbon Stock Devaluation*

Darwin Choi, Zhenyu Gao, Wenxi Jiang, and Hulai Zhang

January 2023

**Abstract**

Using global evidence, we show that high-emission firms tend to have lower price valuation ratios than low-emission firms in the same country, especially in recent years. The price gap coincides with heightened climate awareness following local natural disasters, as well as with the divestment from high-emission stocks by financial institutions and retail investors. In the presence of equity price pressure in the country, high-emission firms reduce carbon emission intensities, increase green innovation activities, and downsize their operations. The changes we identify are unlikely a consequence of tighter environmental regulations, as private high-emission firms do not show the same results.

**JEL Classification: D83, G11, G15, G23, Q54**

**Keywords:** Price Valuation, Divestment, Climate Awareness, Carbon Emissions, Green Innovation

*Choi, Gao, and Jiang are at CUHK Business School, The Chinese University of Hong Kong, and Zhang is at Tilburg University and ESCP Business School. Our correspondences are dchoi@cuhk.edu.hk, gaozhenyu@baf.cuhk.edu.hk, wenxijiang@baf.cuhk.edu.hk, and h.zhang_4@tilburguniversity.edu, respectively. We thank Tim Adam, Sumit Agarwal, Vikas Agarwal, Po-Hsuan Hsu, Emirhan Ilhan, Soh Young In, Marcin Kacperczyk, Santanu Kundu, Kai Lessmann, Fengfei Li, Hao Liang, Peter MacKay, Takashi Onoda, Lynn Pi, Alex Stomper, Dragon Tang, Luke Taylor, Irena Vodenska, Chi Man Yip, Bohui Zhang, and seminar participants at The Asian Development Bank Institute (ADBI) Virtual Workshop on Effective Greenhouse Gas Emission Control Policies, 35th Australasian Finance and Banking Conference, 1st CEPR Rising Asia Workshop, China Accounting and Finance Review 2021 Virtual Conference, China International Conference in Finance 2021, Conference on Asia-Pacific Financial Markets 2020, CREDIT 2021 Compound Risk: Climate, Disaster, Finance, Pandemic (Poster Session), 5th Edinburgh-Shanghai Green Finance Virtual Conference, 1st NTHU Symposium on Sustainable Finance and Economics, Second Sustainable Finance Forum, SFS Cavalcade Asia-Pacific 2022, Virtual Asset Management Seminar Series, Chinese University of Hong Kong, ESCP Business School, Humboldt University of Berlin, Renmin University, Shanghai University of Finance and Economics, and Singapore Management University for helpful comments. We acknowledge the General Research Fund of the Research Grants Council of Hong Kong (Project Number: 14506119) for financial support. Ruikun Wang provides excellent research assistance. An earlier draft of this paper was circulated under the title "Global Carbon Divestment and Firms' Actions." First draft: April 2020.

# 1 Introduction

In recent years, public concerns over climate risks have risen and the urge to combat climate change has become stronger. The Paris Agreement, which aims to limit global temperature rise in this century, was drafted in 2015 and signed by 195 participating member states and the European Union. Governments of many countries are designing new policies and setting long-term greenhouse gas emission reduction targets. Activists organized large-scale climate protests in different cities to demand more action. U.S. surveys run by the Yale Program on Climate Change Communication show that the percentage of adults who think global warming will harm future generations increased from 59% in 2011 to 72% in 2020. Dechezlepretre et al. (2022) conduct a survey in 20 countries. Over 75% of respondents in each country think that "climate change is an important problem" and that their country "should take measures to fight climate change."

Is the increase in climate awareness reflected in stock prices? Using data from 26 major equity markets, we compare the average valuation ratio, measured by price-to-book, price-to-earnings, price-to-sales, or price-to-cashflow, of high-emission firms and that of low-emission firms. Following Choi et al. (2020a), we adopt the definition provided by the Intergovernmental Panel on Climate Change (IPCC), the leading international body for the assessment of climate change, which lists five major industry categories of carbon dioxide and other greenhouse gas emission sources: Energy; Transport; Buildings; Industry (such as chemicals and metals); and Agriculture, Forestry, and Other Land Use (AFOLU). Firms in these industries are labeled as high-emission firms; those in other industries are labeled as low-emission. We show that the price valuation gap between high- and low-emission stocks (emission-minus-clean, EMC price gap) was close to zero before 2011 but negative and growing in magnitude afterward (see Figure I for the value-weighted average price-to-book gap).

The value-weighted average price-to-book ratio in our sample is 4.1, and the EMC price-to-book gap reached about −2 in 2018. A similar pattern is observed if emission firms are defined based on firm-level emission intensities or news-based environmental ratings instead, or in a regression setting that controls for stock characteristics and firm fixed effects.

In the financial market, there also appears to be a recent shift in investors' capital allocation from high-emission firms to cleaner firms, which we term carbon divestment.[1] The Principles for Responsible Investment (PRI) has over 5,000 signatories (with collective assets under management of US$121 trillion) as of 2022. Negative screening, the process of excluding certain sectors or companies from a portfolio, has been one of the most common sustainable investment strategies (Alliance, 2020).[2] Investors allocate more money to funds rated high in terms of sustainability: Morningstar reports that sustainable funds in the U.S. attracted a record level of inflows in 2021. From our data, we estimate that institutional and retail investors reduce their ownership of high-emission firms by 1.2% from 2007 to 2020.

This shift in stock valuation and capital allocation is consistent with a positive shock in the ESG (Environmental, Social, and Governance) factor in Pastor et al. (2021)'s theoretical framework. The ESG factor captures investors' ESG concerns and tastes for green holdings. Pastor et al. (2021) show that, in equilibrium, strong investor ESG preferences create a valuation gap between green and brown firms. To empirically link our findings to climate concerns, we exploit plausible exogenous shocks to investors' attention to climate change at the country level. People's awareness of climate risk increases after experiencing local extreme weather events and natural disasters (Alekseev et al., 2021; Alok et al., 2020; Choi et al., 2020a) (we verify this by examining Google search volume and Bloomberg news publications on the topic of "climate change" in the country). We show that both the EMC price gap and carbon divestment by institutional and retail investors are more prominent

[1]Throughout the paper, we refer to the reduction in exposure to stocks of high-emission firms as carbon divestment, interpreting the term "divestment" in a broad sense—that is, the opposite of investment.

[2]Some of the largest institutional investors, including sovereign wealth funds, asset managers, and university endowments, express concerns about sustainability issues and have committed to fully divesting from the fossil fuel industry. For example, BlackRock announced in 2020 that it would exit investments in thermal coal producers and launch new ETF products that exclude fossil fuel stocks, noting that "sustainability should be our new standard for investing." The world's largest sovereign wealth fund, The Government Pension Fund Global in Norway, sold off all its assets linked to geological exploration and oil and gas production in 2020. Arabella Advisors (2018) report that about 1,000 institutions in 37 countries have committed to divest from the fossil fuel industry. These institutions include faith-based organizations, philanthropic foundations, government institutions, university endowments, and pension funds.

when there are more major natural disasters (provided by Baker et al. (2022)) in a country during a quarter, suggesting that prices and capital allocation decisions are at least partially driven by heightened climate concerns.[3]

In Pastor et al. (2021), the valuation gap between green and brown firms incentivizes firms to become greener, as managers maximize market value. We examine firms' real actions and find evidence that high-emission firms improve their carbon footprints in the presence of price pressure. Using firm-level data provided by Trucost, we show that a more negative EMC price gap in the country in the past is associated with relatively lower $CO_2$ emission intensities by high-emission firms. Widening the EMC price gap by one standard deviation is associated with declines of 5.3%, 2.2%, and 2.4% (relative to the mean values) in Scopes 1, 2, and 3 emission intensities respectively, compared with low-emission firms.[4]

Following Cohen et al. (2020), we identify green patents filed by firms. Green patents are those related to environmental management, water adoption, biodiversity protection, climate change mitigation, and greenhouse gas management. Consistent with Cohen et al. (2020), we show that high-emission firms tend to file a higher proportion of green patents than low-emission firms. We also find that the ratio of green patents to total patents filed by high-emission firms increases following a more negative EMC price gap in the country. A one standard deviation increase in the magnitude of the gap is associated with a 0.23% increase in the ratio of green patents filed by emission firms, relative to clean firms. This result suggests that high-emission firms invest in methods that make them more environmentally

[3]Using FactSet Ownership data, we classify stockholders into financial institutions, blockholders excluding financial institutions, and retail investors. We do not observe retail investors' ownership directly and assume that it is equal to (100%− financial institutions' ownership − blockholders' (excluding financial institutions) ownership). Institutional and retail investors' carbon divestment increased after 2015, which coincides with fossil fuel divestment campaigns that grew rapidly in 2015 (Hirji, 2015) and the adoption of the Paris Agreement. While institutional and retail investors are selling, high-emission firms are generally repurchasing their shares and blockholders such as non-financial institutions, insiders, and corporations are buying stocks of high-emission firms.

[4]Scope 1 emissions are direct emissions from firms' activities. Scope 2 captures indirect emissions from the consumption of purchased electricity, heat, or steam. Scope 3 emissions are all indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company. Our result that high-emission firms become greener to a larger extent than low-emission firms is consistent with lower ESG adjustment costs among high-emission firms in Pastor et al. (2021)'s model and with the price differential between clean and dirty firms exceeding the cost of reforming a dirty firm in Heinkel et al. (2001)'s framework.

friendly.

Facing a higher cost of capital due to their lower price valuation in the equity market, do high-emission firms adjust their financing and operations? We show that high-emission firms significantly reduce their new stock issuance under a larger price gap; they do not increase cash dividend distributions or short/long-term debt financing. Therefore, high-emission firms are more likely to use internal rather than external financing. They also downsize their operations, as evidenced by lower sales, total assets, and capital expenditures.[5]

While we cannot claim that institutional and retail investors affect firms' real decisions in a causal manner, we adopt a triple difference (difference-in-difference-in-differences) approach to link firms' actions to equity price pressure. Our analysis of emission intensities and green patents compares publicly-listed emission firms and clean firms in countries with different price gaps. We repeat this analysis using *private* emission firms and clean firms and do not find the same results. This is expected because private firms do not face the same price pressure. Although it is still possible that some omitted variables simultaneously drive investors' and public firms' decisions, variables affecting both public and private high-emission firms (such as environmental regulations) cannot explain our findings.

At the very least, we observe that stock prices and real decisions made by public firms go in the same direction, the direction that lowers carbon emissions and helps combat climate change. This suggests that the capital market plays a role: while climate awareness may also induce tighter environmental regulations and firms' desire to become cleaner, our differential results between public and private firms highlight the impact of the equity market. In a general equilibrium model, Hong et al. (2021) show that sustainable finance investment mandates create a cost-of-capital wedge between sustainable and unsustainable firms and incentivize unsustainable firms to become sustainable for a lower cost of capital.

Consistent with our international evidence, Bolton and Kacperczyk (2021), Gibson et al. (2021a) and Choi et al. (2020b) also find a decreasing trend in U.S. institutions' exposure

[5]However, this downsizing does not fully explain the decrease in total carbon emissions because emission intensities, defined as emissions divided by sales, also go down.

to stocks of high-emission firms. Boermans and Galema (2019) and Anderson and Robinson (2019) show a similar trend for Dutch and Swedish pension funds, respectively. Rohleder et al. (2022) argue that U.S. and European mutual funds' divestment from carbon-intensive firms exerts pressure on these firms. Chava (2014) finds that U.S. firms with environmental concerns face higher costs of capital, while Hsu et al. (2022) show that U.S. firms with high toxic emission intensity earn higher stock returns, which they term the pollution premium. We add to the literature by systematically examining financial institutions, retail investors, and blockholders in a broad set of markets, following theoretical predictions to establish the association between climate awareness and stock prices and divestment, and emphasizing the role of the equity market by linking price valuation to public firms' emissions and green activities.

We contribute to the literature that studies the intersection of climate change and financial economics. Early work by Nordhaus (1977, 1991, 1992) points out that economic growth is a driver of climate change. Subsequent papers by, for example, Kelly and Kolstad (1999), Weitzman (2009), and Golosov et al. (2014), analyze the implications of risk and uncertainty about climate change on the economy. More recently, a growing field of climate finance examines the role of financial markets in mitigating and hedging climate risk (see, for example, survey articles by Giglio et al. (2021), Hong et al. (2020), and Stroebel and Wurgler (2021)).

Several recent papers examine the effect of shareholder engagement by activist investors (e.g., Chowdhry et al. (2019); Krueger et al. (2020); Broccardo et al. (2022); Oehmke and Opp (2022)). While our tests on firms' actions control for institutional ownership, which proxies for engagement activities (Dyck et al. (2019)), we do not mean to compare the effectiveness of divestment with that of other strategies in reducing emissions. Our view is that these strategies can be adopted by different investors and can co-exist in financial markets. For example, Dasgupta et al. (Forthcoming) show that U.S. socially responsible mutual funds influence nearby plants' emissions through both the voice and exit channels.

The remainder of the paper is structured as follows. Section 2 describes the data. Sections 3 and 4 present the results of the price gap and carbon divestment and their changes during local natural disasters. Section 5 examines firms' real decisions. Section 6 concludes.

# 2 Data

In this paper, we combine several data sources to implement our analysis.

## 2.1 Stock ownership

Institutional and blockholder equity ownership is obtained from FactSet Ownership v5 (see also Koijen et al. (2020)).[6] The detailed construction of equity holdings can be found in the Internet Appendix IA.1.

FactSet gathers its holdings data from a variety of sources, such as regulatory filings, corporate reports, and direct requests from fund managers. Although the frequency of updates varies by market, most institutional investors and companies update ownership data quarterly or even monthly. We interpolate holdings from the last available quarter prior to the perspective quarter for institutions that do not report holdings every quarter or who consistently report holdings longer than a quarter. Our analysis relies on quarterly ownership.

We restrict holdings to common equity and depositary receipts (DR). We categorize equity owners into three groups: institutions, blockholders excluding institutions, and retail investors. The ownership of stocks by institutional investors and blockholders is calculated directly from FactSet ownership data, as equity holdings over the market capitalization of the stock. Then, we define retail ownership as 100% minus institutional ownership minus

[6] FactSet Ownership v5 contains four main tables: 13F holdings (13F), fund level holdings (SOF), institutional stakes holdings (INST), and non-institutional stakes holdings (NINST). The first three tables are our source of institutional holdings while NINST is the source of blockholders' holdings. NINST reports holdings from non-institutional stakeholders and people that are identified as stakeholders. As explained in the Internet Appendix IA.1, some institutional holdings from 13F, SOF, and INST are included in NINST. We remove these holdings to construct the ownership of blockholders excluding institutions.

blockholders' ownership excluding institutions. Since we intend to compare institutional investors' portfolios with market portfolios, we exclude countries with less than 50 institutions or 50 stocks. Our sample contains 44,182 unique securities and 18,708 unique institutions in 26 countries from 2007Q1 to 2020Q4. At the end of 2020, the total market capitalization is 82.8 trillion USD, while the total holdings are 32.0 trillion USD by institutional investors and 10.7 trillion USD by blockholders excluding institutions. See Table I for the list of markets in our sample.

## 2.2 Stock and public company information

Stock price, market capitalization, industry information, and fundamentals are available from FactSet Fundamentals v3. The detailed construction of market capitalization and fundamentals can be found in Internet Appendix IA.2.

Stock prices and shares outstanding are adjusted for company operations such as splits before calculating the market capitalization. Price-to-book ($PB$), price-to-sales ($PS$), price-to-earnings ($PE$), and price-to-cashflow ($PCF$) are calculated using the end-of-quarter market capitalization divided by book equity, total sales, earnings, and net cashflow in the previous year, respectively. All variables are transformed to USD using real-time exchange rates. We follow the procedure in Fama and French (1992) and assume a lag of six months before the fundamentals get public. We winsorize the fundamentals variables within country-year-month at the 1st and 99th percentiles.

To identify high-emission firms, we follow the procedure in Choi et al. (2020a). That is, we adopt the industry definitions provided by the Intergovernmental Panel on Climate Change (IPCC), the leading international body for the assessment of climate change. Five major industry sectors are identified as major emission sources: Energy; Transport; Buildings; Industry (such as chemicals and metals); and Agriculture, Forestry, and Other Land Use (AFOLU). Each sector is further divided into subcategories. We hand-match the IPCC subcategories with FactSet industry codes. Since this IPCC measure is based on industries, it covers all the firms in our sample, a clear advantage for international studies. By comparison, other rating-based measures such as MSCI ESG ratings are only available for a subset of firms in our sample and may be subject to selection issues.[7] Firms that are matched with the IPCC emission industries are classified as high-emission firms, i.e., the indicator $Emission = 1$; the rest of the firms have $Emission = 0$ and are classified as clean firms. The full list of emission industries is in Table IA.I. We also use alternative definitions of high-emission firms: high-emission firms are determined either by their emission intensity (tons of $CO_2$ emission scaled by total sales) or by negative environmental news coverage (provided by RepRisk).

## 2.3 Carbon emission measures

The firm-level emission data are from Trucost. The dataset provides an estimation of companies' $CO_2$ equivalent emission (in tons) on an annual basis. Trucost categorizes emissions into three "Scopes" following the GHG Protocol Corporate Standard: Scope 1 emissions are direct emissions from owned or controlled sources; Scope 2 emissions are indirect emissions from the generation of purchased energy; and Scope 3 emissions are all indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions.[8] We use all three scopes of carbon emission at the firm-year level from 2007 to 2020.

Trucost covers mostly public firms and some private firms. In our sample from 2007 to 2020, Trucost covers 14,961 unique public firms and 5,409 private firms in 26 countries. The private firms in Trucost do not come with information on size or other financials or with a reliable way to match other databases of private firms (e.g., Obris Global).

We merge Trucost with FactSet via ISIN. We define our firm-year level emission measures, *Log Scope1*, *Log Scope2*, *Log Scope3* as the log of one plus scope 1, scope 2, and scope 3 emissions in tons, and *S1int*, *S2int*, *S3int* as the scope 1, scope 2, scope 3 emissions over total sales. Carbon emissions are winsorized within country-year at the 95th percentile.

[7] See page 1120 of Choi et al. (2020a).

[8] See https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf.

## 2.4 Company patent information

The patent information is from Bureau van Dijk's (BvD) Orbis IP database. The database covers both public and private firms around the world. We retrieve the patents' priority date and their International Patent Classification (IPC) code. Priority date specifies the earliest filing date of patent applications. We use IPC code to classify each patent into green patent or non-green patent based on the guidelines from the Organization for Economic Co-operation and Development (OECD) and the procedure in Cohen et al. (2020).[9] According to OECD's guideline, patents that are environment-related belong to several types such as environmental management, water adoption, biodiversity protection, climate change mitigation, and greenhouse gas management. Haščič and Migotto (2015) offer a detailed description of how to identify environmental-related patents. We calculate the ratio of green to all patents that a firm files for each quarter and merge it with other databases via firms' ISIN code. The patent data in our sample are from 2007 to 2019.

## 2.5 Private firm information

We obtain the total assets for private firms from BvD Orbis Global database. The accounting data for private firms are available from 2010 to 2018.

To match each public firm with comparable private firms, we construct a propensity matching score based on country, industry, and total assets. The total assets for public firms are taken from BvD Orbis Global database and, if missing, from FactSet Fundamentals v3. The matched private firm must be in the same country and industry as the public firm and has total assets that are among the three closest to the public firm. For public firms and the matched private firms, we require that they have filed at least one patent between 2010 and 2018.

[9] For OECD's identifications of environment-related technologies, see `https://www.oecd.org/environment/consumption-innovation/ENV-tech%20search%20strategies,%20version%20for%20OECDstat%20(2016).pdf`.

## 2.6 Natural disasters

The natural disaster data originate from the Center for Research on the Epidemiology of Disasters' EM-DAT database.[10] The EM-DAT data include information on disaster type, date, location, and impact. For a disaster to be entered into the database, at least one of the following conditions must be met: (1) ten or more people killed, (2) a hundred or more people impacted, (3) a state of emergency declared, and (4) a request for international help. Droughts, earthquakes, insect infestations, pandemics, floods, extreme temperatures, glacial outbursts, landslides, storms, volcanoes, wildfires, and hurricanes are among the disasters covered by the EM-DAT data.

We use the measure developed by Baker et al. (2022), *Natural Shocks*, which equals the number of major natural disasters in a country over the course of a quarter. A major natural disaster is one that kills 100 people or damages more than 0.1 percent of the country's GDP. If two or more incidents of the same type occur in a country-quarter, the measure *Natural Shocks* will be added by one to avoid double counting recurring but linked disasters. For example, *Natural Shocks* will obtain a value of two (= one earthquake plus one wildfire) if a country experiences two earthquakes and one wildfire in a quarter. We use disaster data from the first quarter of 2004 through the fourth quarter of 2020.

## 2.7 Google Search Volume Index and Bloomberg News Trends

We use Google Trends' (also see Choi et al. (2020a); Alekseev et al. (2021)) internet search activity, which provides a Search Volume Index ($SVI$) for the topic "climate change", to measure the attention to and awareness of climate change by retail investors.[11] We download the $SVI$ for all countries in the world every quarter between 2004Q1 and 2021Q4. Google Trends returns an $SVI$ in the range of 0 to 100 every quarter. As a result, the

[10] For more information, see https://www.emdat.be/.

[11] Google Trends provides SVI for "topics" and "search terms." Topics address misspellings and searches in different languages, because Google groups different searches that have the same meaning under a single topic. For details, see the official Google Search blog: https://search.googleblog.com/2013/12/an-easier-way-to-explore-topics-and.html.

country with the most searches obtains an $SVI$ of 100 each quarter. $SVI$ for other nations is calculated as a percentage of the most searched country's volume. A $SVI$ of zero indicates that there are no or very few search volumes.

Bloomberg provides global news publications on the topic of "climate change", which is proxy for the attention to and awareness of climate change by institutional investors. The news is collected from a variety of sources, such as newspapers, social media, and Bloomberg itself. Our Bloomberg news count reflects the total number of "climate change" news related to a specific country each month since March 2012.[12]

# 3 Global Devaluation of Carbon Stocks

## 3.1 Country-level EMC price gap

We examine the valuation gap between emission and clean firms at the country level and how it has evolved globally in recent years. As described earlier, our categorization of emission firms builds on the industry definitions provided by IPCC. The industry-based approach is more transparent and covers all firms over a longer period than firm-level environmental ratings provided by commercial vendors (such as MSCI ESG Ratings and Sustainalytics). Also, those ratings are usually industry-adjusted and do not capture the heterogeneity in the level of greenhouse gas emissions across different industries.[13]

For each country $m$ at quarter $t$, *EMC Price Gap* equals the average price-to-book ratio (PB) of emission firms minus the average PB of clean firms in the country. PB is calculated with the firm's market capitalization at quarter $t$ and book equity value observed at the most recent year-end relative to quarter $t$. Similarly, we also calculate price-to-sales ratio (PS), price-to-earnings ratio (PE), and price-to-cashflow ratio (PCF) as alternative valuation

[12] We search "climate change" with country names in Bloomberg "NT" function. We use news publications from all sources.

[13] See Choi et al. (2020a,b) and Pastor et al. (2022) for more discussion.

measures.[14] We use both value-weighted average by firm size (VW) and equal-weighted average (EW) in our analysis. We consider value-weighted *EMC PB Gap* our primary measure, while our results, as shown later, are similar and robust to using the various versions of EMC price gap. The country-level EMC price gap captures the aggregate price pressure and implied financing costs for emission firms, and can be a function of the overall level of investors' climate concern in the country.

Before we conduct the country-level analysis, Figure I visualizes the global trend of *EMC Price Gap*. The dashed (solid) line plots the quarterly value-weighted average of PB ratio of all clean (emission) firms in our global sample; the bar represents the gap between the two. One can see that the gap was not significant before 2011 but has become increasingly sizeable over time. In recent years after 2018, the gap of PB ratio between emission and clean firms reaches about $-2$.

Panel A of Table II presents summary statistics at the country level. Over our sample period of 2007 to 2020, the average *EMC Price Gap* of various versions appears to be negative. For example, the *EMC PB Gap (VW)* equals $-0.78$ (with a standard deviation of 1.80), which is sizeable given that the value-weighted average PB of public firms is 4.1 in our sample.

Next, we run the regression of *EMC Price Gap* on a time trend variable, *Trend*, that is,

$$\text{EMC Price Gap}_{m,t} = \alpha + \beta \text{Trend}_t + Control_{m,t} + \sigma_m + \epsilon_{m,t} \tag{1}$$

where $\sigma_m$ refers to country fixed effects. $Control_{m,t}$ refers to a set of countries' demographic and economic characteristics, including log GDP per capita, female ratio, corruption, government effectiveness, political stability, regulatory quality, rule of law, and accountability (see the definitions in Internet Appendix IA.2). We cluster standard errors by year-quarter.

Table III reports the results. In Panel A, we value-weight EMC price gap in columns (1)–(4) and equal-weight in columns (5)–(8). We consider four price-to-fundamental ratios:

[14] Firm-year observations with negative earnings, book value, or cash flow are dropped.

PB, PS, PE, and PCF. Across all specifications, the coefficients of the time trend variable *Trend* are all negative and statistically significant at the 1% level. The economic magnitude is also meaningful. Column (1), for example, suggests that the PB ratio of carbon-intensive firms decreases by $0.088 (= 4 \times 0.022)$ per year relative to clean firms, whereas the mean of *EMC PB Gap (VW)* equals $-0.781$.[15]

Panel B repeats the same analyses but splits emission firms into energy and non-energy sectors (i.e., Transport; Buildings; Industry; and AFOLU) and compares each separately with clean firms. For brevity, we only report the results using value-weighted EMC price gaps. In columns (1)–(4), where we examine non-energy emission firms' valuation, the coefficients of *Trend* are all statistically negative. This suggests the devaluation effect on carbon firms is not driven by shocks to the energy sector (e.g., the oil crisis). As shown in (5)–(8), energy firms also experience devaluation of a similar magnitude over the sample period.

**Robustness tests** We conduct several robustness tests using alternative emission measures and regression specifications; results are reported in the Internet Appendix. In Panel A of Table IA.II, emission firms are determined by their emission intensity (tons of $CO_2$ emission scaled by total sales). When a firm's $CO_2$ intensity is among the top (bottom) 30% in the country-year-quarter, the firm is regarded as a high (low) $CO_2$ intensity firm.[16] *EMC Price Gap* is then calculated as the difference of price ratio between high and low $CO_2$ intensity firms. In Panel B, we use a news-based environmental rating provided by RepRisk. A firm is classified as emission if the firm has been covered by negative environmental news in the past 12 months, and as clean otherwise. Both panels show that the devaluation pattern of emission firms is significant and robust, with a similar economic magnitude to those in Table

[15]We do not expect this trend to continue at the same pace forever; the estimate applies to our sample period. It is possible for this trend to slow down or even reverse in the future if climate awareness stops increasing. Zhang (2022) shows that in-sample sustainable flows and climate-concern shifts explain the stock returns earned by carbon firms and clean firms internationally.

[16]$CO_2$ emission here equals the sum of scope 1, 2 and 3 emission. Results are robust if we use each scope separately.

III.[17]

In Internet Appendix Table IA.III, instead of using the trend variable *Trend*, we use year dummies (year of 2007 as the base). We focus on the coefficient before the interaction terms of year dummies with *Emission*; one can see that the coefficients become more negative and significant around 2013 across different specifications, consistent with the baseline result.

## 3.2 Firm-level evidence

In this subsection, we examine the devaluation effect on carbon stocks at the individual stock level. In this way, we better control for stock characteristics and firm fixed effects that could influence firms' valuation. Specifically, we conduct a pooled regression using the global sample of all firms to examine the difference in valuation between emission and clean firms and how the difference evolves over recent years. We follow the specification of Hong and Kacperczyk (2009), that is, for firm $i$ and quarter $t$,

$$\text{Log PB}_{i,t} = \alpha + \beta_1 \text{Emission}_i + \beta_2 \text{Emission}_i \times \text{Trend}_t + X'_{i,t}\Gamma + \sigma_m + \delta_t + \epsilon_{i,t} \quad (2)$$

where *Emission* is a dummy variable that equals one if the firm belongs to one of the emission industries defined by IPCC. $\sigma_m$ and $\delta_t$ refer to the country and year-quarter fixed effects, respectively. In two alternative specifications, we use firm fixed effects and further add country times year-quarter fixed effects, which can rule out the possibilities that certain firm invariant features or some country-specific events in a quarter drive firm valuation, respectively. $X_{i,t}$ represents our controls for firm characteristics that may be correlated with valuation, including log of total assets, book leverage, cash to total asset ratio, and return on equity (ROE). The left-hand side variable is the log of price to book ratio (*Log PB*), and we also use price to sales ratio (PS), price to earnings, and (PE) price to cashflows ratio (PCF) as alternative measures. Based on our country-level findings, we expect $\beta_2$ to be negative,

[17] In untabulated results, we find the valuation gap is weaker when we use industry-adjusted emission measures (e.g., MSCI E ratings), suggesting the effect is more pronounced across industries.

that is, the valuation of emission firms has become lower than clean stocks in recent years. Standard errors are double clustered by firm and by year-quarter.

Table IV presents the results. In column (1), we only include *Emission*, control variables, and year-quarter and country fixed effects. It shows that the coefficient before *Emission* is −0.115 and statistically significant. This implies that during our sample period from 2007 to 2020, emission firms exhibit an 11.5% discount on their valuation relative to clean companies. This is comparable to the price of sin effect identified by Hong and Kacperczyk (2009), who show that the discount for sin stocks is about 15%.

Consistent with the price discount we document, Chava (2014), Bolton and Kacperczyk (2021), and Hsu et al. (2022) show that high-emission firms are like sin stocks and earn higher stock returns. We further examine how the price gap between emission and clean firms varies over time. We add an interaction term between *Emission* and *Trend* and use firm fixed effects (thus the coefficient of *Emission* is subsumed) in column (2). The coefficient before the interaction term is significantly negative, implying that the pricing gap between carbon and clean firms has grown larger in magnitude in the recent decade. In terms of economic magnitude, the devaluation for emission firms increases by 0.8% per year. In column (3), we add country times year-quarter fixed effects, and the estimates are virtually the same. Last, we repeat the regressions in columns (1) to (3) but use *Log PS*, *Log PE* or *Log PCF* as the dependent variable. As shown in columns (4)–(12), the results are highly similar and significant with minor differences in magnitude.

## 3.3 Evidence of carbon divestment

Given the strong price effect we show above, here we examine whether this is associated with a trend of divesting carbon firms by retail or institutional investors. As more and more investors are aware of climate change, they may start to be concerned about potential risks (both physical and regulatory) for emission firms' future business, or they may adopt environmental-friendly investment preference or green portfolio mandates. Those can lead to systematic carbon divestment or under-weight emission stocks in investors' portfolios.

Using equity positions of institutions and blockholders reported in FactSet Ownership v5, we calculate quarterly *Institutional Ownership* for each stock as the fraction of shares outstanding held by financial institutions. *Retail Ownership* equals one minus *Institutional Ownership* and the fraction of shares owned by blockholders (excluding institutions). The regression specification is similar to Equation (2),

$$\text{Ownership}_{i,t} = \alpha + \beta \text{Emission}_i \times \text{Trend}_t + X'_{i,t}\Gamma + \gamma_i + \delta_t + \epsilon_{i,t} \quad (3)$$

where we control for firm fixed effects, as the investment composition (e.g., institutional vs retail) varies dramatically across countries and among firms with different size and so on, and for year-quarter fixed effects, because over the period institutional ownership increases significantly for most countries. Further, we also add country times year-quarter fixed effects to allow such a trend, if any, to vary across countries. Control variables are the same as Equation (2). Standard errors are double clustered by firm and by year-quarter. We expect $\beta$ to be negative.

Table V presents the results. In column (1), the left-hand side variable is the summation of institutional and retail ownership. The coefficient before the interaction term between *Emission* and *Trend* equals $-0.044$ and is statistically significant. When we add more strict, country times year-quarter fixed effects in column (2), the point estimate is reduced to $-0.023$ but remains statistically significant at the 5% level. In columns (3) and (4), we separate institutional and retail ownership, and economically, the two exhibit a similar tendency of divestment. We further decompose institutional ownership into domestic and foreign institutional ownership, and we find that the coefficient on the interaction term is statistically significant only for domestic institutional ownership, as shown in columns (5) and (6).

Based on the estimation in column (2), it implies that compared with the clean firms in the same country, institutional and retail investors together reduce their ownership of emission firms by about 0.09% per year. In other words, the ownership gap accumulates to about 1.2% from 2007 to 2020, which translates into the dollar amount of $336 billion in divestment globally.[18] Interestingly, domestic institutions, rather than foreign institutions, divest emission firms more aggressively over time. Our results here also suggest that blockholders or carbon firms themselves are the ones who buy the divestment sales.

We try to visualize the divestment trend using an alternative way to gauge the extent to which investors underweight emission firms at the global or country level. Specifically, we compare the carbon share of an investor's portfolio with the carbon share of the market. We label the difference as *Active Carbon Share*. Then, we take the value-weighted average of *Active Carbon Share* for all institutional and retail investors. Figure II plots the trend of global average *Active Carbon Share*. It shows that *Active Carbon Share* decrease steadily over the years, in particular, around the year 2015 (which corresponds to the passage of the Paris Agreement). In 2020, global investors under-weight carbon-intensive firms by about 1.2% relative to the market index.

# 4 Local natural disasters as exogenous shocks

## 4.1 Natural disaster and attention to climate change

The previous section documents stylized and salient facts about carbon firm devaluation and divestment. While there can be other possibilities, we argue that the increased awareness of climate change among investors is at least one of the driving forces. As more investors are aware of climate change, some may take environmental concerns as a new social norm and adopt green investment mandates by themselves or by pushing their delegated institutions, and some may start to take into account potential climate risk, both physical and regulatory,

[18] This is equal to 1.2% $\times$ total market value of high-emission firms in 2020Q4 = 1.2% $\times$ 28.0 trillion USD = $336 billion.

associated with emission firms' business and future profitability. Either or both channels can lead high-emission firms or industries to exhibit lower valuation and ownership than clean companies in the same country and a further reduction in valuation and ownership as more investors are aware of climate change.

The time trend variable we use in the previous section can coincide with other confounding events, not only the increased climate awareness. To formally test our conjecture and identify the causal effect, we exploit the occurrence of local natural disasters as plausibly exogenous shocks to investors' attention to climate change. Several studies find that residents tend to become aware of climate issues after experiencing local extreme weather events and natural disasters (e.g., Choi et al. (2020a), Anderson and Robinson (2019), and Boermans and Galema (2019)). More importantly, the increased climate awareness can translate into real actions by affected residents, such as switching their pension investment to green mutual funds.

We use the measure developed by Baker et al. (2022), *Natural Shocks*, which equals the number of major natural disasters in a country during a quarter. Major natural disasters refer to those cause either 100 deaths or real damages of more than 0.1% of national GDP. Those extreme events usually attract wide attention and media coverage and can potentially generate significant impacts on residents. Specifically, the data cover extreme weather events such as droughts, earthquakes, insect infestations, pandemics, floods, extreme temperatures, avalanches, landslides, storms, volcanoes, fires, and hurricanes.

Before running our main tests, we verify if the occurrence of extreme weather events induces increased attention to and awareness of climate change. We use two measures of attention to climate change. The first one is the Google search volume on the topic of "climate change" at the country-quarter level. When it is downloaded, the Google search volume index (SVI) data is normalized by quarter; that is, the country with the highest search volume on climate change among all countries during the quarter will be assigned 100 for SVI. Therefore, in the panel regression, we control for year-quarter fixed effects to address this. Specifically, for country $m$ and quarter $t$, we run the following regression,

$$\text{Log SVI}_{m,t} = \alpha + \beta \text{Natural Shocks}_{m,t} + \delta_t + \epsilon_{m,t}. \tag{4}$$

The second measure is the number of news reports on Bloomberg using the keywords of "climate change" and the country name in that quarter. We take the log of the variable, labeled as *Log News*, and use it as the dependent variable of Equation (4). Google searches are mostly done by ordinary households and thus presumably better capture the attention of retail investors. As a complement, Bloomberg news is likely read by financial professionals and thus can be a valid proxy for institutional attention.

Table VI shows the results. According to column (1), the coefficient before *Natural Shocks* is significantly positive. We further control for country fixed effects in column (2), and the result remains significant. The point estimate implies that upon the occurrence of one natural shock, Google search volume on climate change related issues increases by 6.3%. In columns (3) and (4), the left-hand side variable of the regressions is *Log News*, and we find consistent results. After controlling for country fixed effects in column (4), the estimates suggest that the occurrence of one local natural disaster in a country is associated with 4.1% more news reports covering climate change in the country. The results confirm the validity of using natural disasters as shocks to climate awareness.

## 4.2 Natural disaster and carbon stock devaluation and divestment

Next, we examine whether the occurrence of local natural disasters induces EMC price gap in the country. Specifically, we replace the time trend variable in Equation (2) with *Natural Shocks* and conduct the following firm-level regression,

$$\text{Log PB}_{i,t} = \alpha + \beta_1 \text{Natural Shocks}_{m,t} + \beta_2 \text{Emission}_i \times \text{Natural Shocks}_{m,t} + X'_{i,t}\Gamma + \gamma_i + \delta_t + \epsilon_{i,t} \tag{5}$$

where we control for firm fixed effects and year-quarter fixed effects. $\beta_2$ is expected to be negative, as upon the occurrence of a natural disaster, emission firms should exhibit a lower price ratio than clean stocks. The same set of stock characteristics, $X_{i,t}$, as in regressions of Equation (2) are used as control variables.

Table VII presents the results. In column (1), the left-hand side variable is *Log PB*. The coefficient before the interaction term between *Emission* and *Natural Shocks* equals $-0.016$ and is statistically significant. The coefficient before *Natural Shocks* is insignificant. In column (2), we add country times year-quarter fixed effects. This is to mitigate any possible country-quarter level events that impact the valuation of all public firms. Thus the variable *Natural Shocks* itself is subsumed in the regression. The coefficient before the interaction term between *Natural Shocks* and *Emission* remains significantly negative. In column (3), we further add *Emission* times year-quarter fixed effects, to rule out the possibility that in certain quarters the valuation gap between emission and clean firms may vary due to other reasons; the effect remains robust, if not even stronger in magnitude. In columns (4) to (12), we use alternative price ratios (*Log PS*, *Log PE*, and *Log PCF*), and the results are similar and statistically significant in 7 out of 9 specifications. In terms of economic magnitude, upon the occurrence of a natural disaster, the valuation ratio of emission firms decreases by 0.7–2.1% relative to clean firms in the same country.

Next, we examine the effect of natural disasters on investor ownership. We run the following regression,

$$\text{Ownership}_{i,t} = \alpha + \beta_1 \text{Natural Shocks}_{m,t} + \beta_2 \text{Emission}_i \times \text{Natural Shocks}_{m,t} + X'_{i,t}\Gamma + \gamma_i + \delta_t + \epsilon_{i,t} \tag{6}$$

where the specification of the independent variables is the same as Equation (5), and the dependent variable is changed to the ownership measures. Table VIII presents the results. We first examine the summation of institutional and retail ownership; we control for firm and year-quarter fixed effects in column (1), add country times year-quarter fixed effects in column (2), and *Emission* times year-quarter fixed effects in column (3). We find that upon the occurrence of a natural disaster, institutions and retail investors reduce their ownership of emission firms by 0.43–0.55% relative to that of clean firms in the same country. The effects are statistically significant.

In columns (4) and (5), we examine institutional and retail investors separately. We find that both types of investors exhibit the significant tendency of divesting carbon stocks; institutions contribute one-third of the total effect shown in column (2), while retail investors contribute the rest two-thirds. The fact that retail investors react more strongly to natural events is consistent with the findings of previous studies (e.g., Choi et al. (2020a)). In columns (6) and (7), we further decompose institutional ownership into domestic and foreign investors. Similar to what we find in Table V, it is mostly domestic institutions that divest carbon firms upon a natural disaster. This result is natural as domestic institutions are the ones who experience the event.

Note that while the occurrence of natural disasters can induce both devaluation and divestment of carbon stocks, we do not intend to claim a causal relationship between devaluation and divestment (one is the cause or consequence of the other). The association between the two can be driven by several channels, which is beyond the scope of our paper. In the rest of the paper, we investigate the real impact of EMC price gap on firms' actions.

# 5 Firm actions

A natural question that follows is whether such price pressure can push companies to lower emissions and upgrade to cleaner technology. These actions can be driven by the clientele channel: socially responsible investors may continue to sell off their holdings if the company does not plan to improve its carbon footprint. The management of the companies that cares about their stock price will react and improve their carbon footprint. We, therefore, hypothesize that carbon-intensive firms in countries with lower price valuation ratios for high-emission industries are likely to take these actions.

## 5.1 The impact on carbon emissions

We first examine firms' actions on carbon emissions. We investigate Scopes 1, 2, and 3 emissions, respectively, to understand the impact on both direct emissions and indirect emissions. Specifically, we run the following cross-sectional regression:

$$\begin{aligned} \text{SNint}_{i,t} =& \beta_1 \text{EMC Price Gap}_{m,t-1} + \beta_2 \text{Emission}_i \times \text{EMC Price Gap}_{m,t-1} \\ & + \text{Emission}_i \times \text{IO}_{i,t-1} + \text{Emission}_i \times \text{ESG Disclosure}_{m,t} + X'_{i,t}\Gamma + \gamma_i + \delta_{m,t} + \epsilon_{i,t}, \end{aligned} \quad (7)$$

where *SNint* is emission intensity, defined as Scope $N$ emissions divided by total sales, where $N \in \{1, 2, 3\}$.[19] *Emission* equals one when the firm belongs to high-emission industries and zero otherwise. *EMC Price Gap* is the difference between the value-weighted average valuation ratio of high-emission firms and the value-weighted average of low-emission firms in country $m$. We control for firm characteristics in $X_{i,t}$ including price ratios, the natural logarithm of one plus total assets, book leverage, total cash and equivalents divided by total assets, and ROE. $\gamma_i$ denotes firm fixed effects. $\delta_{m,t}$ denotes county-year fixed effects. Standard errors are clustered by firm.

Inspired by Dyck et al. (2019), the independent variables include institutional ownership, as well as its interaction with *Emission*, to control for possible institutional engagement with emission activities. We also include a dummy variable, *ESG Disclosure*, which takes a value of 1 if the country-year has mandatory ESG disclosure requirements for listed firms (absorbed by the country-year fixed effects), and its interaction with *Emission*. This is to control for the effect shown by Krueger et al. (2021): mandatory ESG disclosure regulation improves the corporate information environment and reduces negative ESG incidents.

[19] We consider emission intensity here to control for the potential downsizing effect under the price pressure which we will elaborate later in this section. In Table XI, we also report the results of emission levels. Indeed, emissions in all three scopes decrease significantly in countries facing higher price pressure on emissions industries.

Our focus lies in the interaction term *Emission*×*EMC Price Gap*, that is, whether high-emission firms tend to take more actions in countries facing higher price pressure on emissions industries. Table IX reports the results for all the public firms in our sample. We use average price gaps over the past year in the country. Since we expect firms under high price pressure to lower their $CO_2$ emission, $\beta_2$ should be positive.

We report the results using the price-to-book ratio for *EMC Price Gap*. Column (1) reports the impact on Scope 1 emissions. The result is both statistically and economically significant. A one standard deviation increase in the magnitude of *EMC Price Gap* (0.927) (making *EMC Price Gap* more negative) is associated with an 8.0 decrease in emission intensity of carbon firms, that is, 5.3% relative to the mean value (150.664).

We then turn to firms' Scopes 2 and 3 emissions in columns (2) and (3) by using *S2int* and *S3int* as the left-hand-side variable. The results are consistent. Economically, a one standard deviation increase in the magnitude *EMC Price Gap* (0.927) is associated with a 0.9 (2.2% relative to the mean value of 40.070) decrease in Scope 2 emission intensity and a 4.0 (2.4% relative to the mean value of 165.572) decrease in Scope 3 emission intensity. Firms reduce their emissions substantially among all three scopes of the GHG Protocol Corporate Standard, suggesting the role of price pressure on both direct and indirect emissions of firms. The large magnitude of Scope 3 emissions implies that firms do not seem to outsource their emissions to upstream or downstream value chains in order to reduce their direct emissions.

Regarding controls, we find that institutional ownership has an insignificant impact on emission intensities for Scopes 1 and 2, while a significant, negative effect on Scope 3 emission intensity. Although this seems to suggest that institutional engagement does not play a role in reducing carbon firms' direct emissions, we acknowledge that institutional ownership can be an imperfect proxy for engagement in our setting.[20] Also, since our comparison is across industries, it can be the case that engagement is more effective within-industry.

[20] To establish causality, Dyck et al. (2019) use the 2010 BP Deepwater Horizon oil spill as an unexpected shock and find that firms with greater institutional ownership at the time of the shock improve their environmental performance more.

In addition, the coefficient on the interaction between *ESG Disclosure* and *Emission* is significantly negative for Scope 1 emission intensity while is insignificant for Scopes 2 and 3. The results suggest that ESG disclosure requirement tends to significantly reduce listed firms' direct emission intensity (Scope 1). However, the effects are insignificant for indirect emissions measured by Scopes 2 and 3. In contrast, after controlling for the proxies for institutional engagement as well as mandatory ESG disclosure regulations, the impacts of price gaps on both direct (Scope 1) and indirect (Scope 3) emission intensities are statistically and economically significant.

We present the robustness results in the Internet Appendix Table IA.V using alternative price gap measures including the price-to-sales, price-to-earnings, and price-to-cashflows ratios. Consistently, we find emission firms reduce their emission intensities under higher price pressure for different measures of price gaps.

## 5.2 The impact on green innovation

Next, we examine firms' innovation activities using patent data. We compare green patents filed by publicly traded carbon and clean firms in countries with different valuation gaps and expect that public carbon firms tend to file more green patents under higher price pressure.

For each firm, we count the total number of patents filed every quarter, and the number of patents classified as green patents based on the classification in Cohen et al. (2020). Then, we calculate *Green Ratio* as the number of green patents to that of all patents. We run the following panel regression at year-quarter level,

$$\begin{aligned} \text{Green Ratio}_{i,t} =& \beta_1 \text{EMC Price Gap}_{m,t-1} + \beta_2 \text{Emission}_i \times \text{EMC Price Gap}_{m,t-1} \\ &+ \text{Emission}_i \times \text{IO}_{i,t-1} + \text{Emission}_i \times \text{ESG Disclosure}_{m,t} \\ &+ X'_{i,t}\Gamma + \gamma_i + \delta_{m,t} + \epsilon_{i,t}, \end{aligned} \tag{8}$$

Similar to other regressions, we focus on the interaction term, that is, whether high-emission firms tend to increase green patenting in countries facing higher price pressure on emissions industries. Based on our hypothesis, we expect $\beta_2$ to be negative. Table X presents the results. We use the past twelve quarters average price gaps *EMC Price Gap* based on the price-to-book ratio.[21] Column (1) reports the results for the regression without firm fixed effects after controlling for firm-level characteristics, including the price-to-book ratio, the natural logarithm of one plus total assets, book leverage, total cash and equivalents divided by total assets, and ROE. In column (1), the coefficient on *Emission* is significantly positive, suggesting that high-emission firms tend to file a larger proportion of green patents than clean firms do, which is consistent with the findings in Cohen et al. (2020). More importantly, publicly-traded high-emission firms tend to file more green patents, as a fraction of total patents, than clean firms when countries have wider pricing gaps, shown by the significant, negative coefficient on the interaction between *Emission* and *EMC Price Gap*.

In terms of economic magnitude, in column (1), a one standard deviation increase in the magnitude of *Price Gap* (0.766) is associated with a 0.23% rise in *Green Ratio*, or 12% relative to the mean value of *Green Ratio* (1.943%). The estimates from columns (2) are similar after including firm fixed effects (which absorb the indicator for high-emission firms *Emission*) and county-year-quarter fixed effects (which absorb the past twelve quarters average price gaps *Price Gap*). In column (3), we further add institutional ownership and the ESG disclosure dummy, as well as their interactions with *Emission*, to control for the possible effects of institutional engagement and ESG disclosure regulations. Interestingly, although institutional ownership is associated with more green patenting for low-emission firms, its effect on high-emission firms appears insignificant. Similarly, the effect of mandatory ESG disclosure requirements on high-emission firms is also insignificant. In contrast, high-emission firms in countries with wider pricing gaps still file significantly more green patents, as a

[21] We consider the past twelve quarters average price gaps because it takes time for firms to relocate research resources and file patents. Our results remain robust even if we consider average price gaps over the past year.

fraction of total patents, than clean firms.

## 5.3 Operations and financing

Our findings imply that carbon public firms tend to reduce carbon emission intensities and increase green patenting ratios, although they are confronted with higher costs of capital from equity markets due to lower price valuation ratios for high-emission industries. Then how do they adjust their operations and financing to become greener? To answer this question, we examine whether firms downsize their operations including sales, total assets, capital expenditures, total emissions, and total patent applications in the presence of price pressure. We also investigate their financing channels in response. Specifically, we conduct the following panel regressions:

$$\begin{aligned}\text{Operation/Financing}_{i,t} =& \beta_1 \text{EMC Price Gap}_{m,t-1} + \beta_2 \text{Emission}_i \times \text{EMC Price Gap}_{m,t-1} \\ &+ \text{Emission}_i \times \text{IO}_{i,t-1} + \text{Emission}_i \times \text{ESG Disclosure}_{m,t} \\ &+ X'_{i,t}\Gamma + \gamma_i + \delta_{m,t} + \epsilon_{i,t},\end{aligned} \tag{9}$$

where the dependent variable represents the size of operations in various dimensions: the log of one plus sales, *Log Sales*, the log of one plus total assets, *Log Total Assets*, total capital expenditures over lagged assets, *CapEx*, the log of one plus carbon emissions in all three scopes (*Log Scope1*, *Log Scope2*, and *Log Scope3*), and the total number of patents filed by each firm each quarter (*Total Patent*). We also consider different financing channels including total payout (dividend plus repurchase) and stock repurchases, divided by total earnings; new stock issuance, divided by lagged market capitalization (*Payout Ratio*, *Repur. Ratio*, and *Stock Sale Rate*); as well as net cashflows from short-term debt and long-term debt, divided by lagged total assets (*ST Debt/Total Assets* and *LT Debt/Total Assets*). For independent variables, *EMC Price Gap* is the difference between the value-weighted average price-to-book of high-emission firms and the value-weighted average of low-emission firms in country $m$ over the past year and *Emission* is an indicator of high-emission industries based on IPCC's categorization. In addition, we add firms' institutional ownership and the ESG disclosure dummy (which is absorbed by country-year fixed effects), as well as their interactions with *Emission* as controls for institutional engagement and ESG disclosure regulations. We control for firm characteristics in $X_{i,t}$ including price-to-book ratio, total assets, lagged book leverage, cash-to-total assets ratio, and ROE. We also control for country-year fixed effects as well as firm fixed effects. Standard errors are clustered by firm.

Table XI presents the results. As shown in columns (1) to (3), We find that carbon-intensive public firms tend to downsize their operations as evidenced by lower sales, total assets, and capital expenditures under the price pressure. Correspondingly, they significantly reduce their carbon emissions in all three scopes (shown in columns (4) to (6)) than clean firms do, when countries have wider pricing gaps. Nonetheless, this downsizing cannot fully explain the reduction in carbon emissions. As discussed in Table IX previously, emission intensities, defined as total emissions divided by sales, decrease for carbon firms in the presence of price pressure.

Similarly, in column (7) of XI, the coefficient on *Total Patent* is significantly positive, suggesting that carbon firms tend to file fewer patents than clean firms do under price pressure, consistent with their behaviors of operation downsizing. However, given the reduction in total patent applications, they are more likely to allocate their resources to green innovations. As a consequence, carbon firms tend to have a higher green ratio in their patent fillings, as evidenced in Table X.

In terms of financing channels, as shown in columns (8) to (12), when facing higher price pressure on high-emission industries, carbon-intensive public firms tend to reduce their new stock issuance. The estimates for cash dividend distributions and the cash flows from both short- and long-term debts are insignificant. Interestingly, these firms increase their stock repurchases in the presence of price pressure. Together with the results in Table V, it implies that high-emission firms are repurchasing their shares and blockholders are buying stocks of high-emission firms when retail and institutional investors are selling. The estimates for total payouts including both repurchase and dividend appear insignificant although carbon firms significantly increase their stock repurchases with wider pricing gaps. Our findings suggest that carbon-intensive firms tend to downsize their operations and reduce their external financing (especially equity financing) in the presence of high price pressure from publicly traded markets.

## 5.4 Private firms as a comparison

Finally, to pin down the underlying mechanism, we conduct similar analyses on private firms. That is, if carbon stock devaluation is correlated with other country-level confounding events, such as more environmental regulatory policies, we should find similar results for private firms in those countries. If this is not the case in the data, it will support our hypothesis that the price pressure from public stock markets incentivizes firms to reduce their carbon emission intensities.[22]

Since control variables are not available for the private firms in Trucost, we run the regressions of emission intensities and levels for all three scopes for the sample of private firms without controls (but still with firm and country-year fixed effects). As shown in Panel A of Table XII, most of the coefficients on the interaction term $\beta_2$ are insignificant or significantly negative, suggesting that private carbon firms do not reduce their emissions in the presence of price pressure, which supports our conjecture.[23]

As Orbis data provide several characteristics of private firms, we are able to match each

[22]While regulatory policies should apply to both public and private firms, it is possible that exchanges around the world impose stricter disclosure requirements on public firms. In Tables IX and X, we control for a dummy variable that captures the mandatory ESG disclosure requirements for listed firms (the data are provided by Krueger et al. (2021)), and the effect of price pressure on public carbon firms remains statistically significant.

[23]Note that the insignificant coefficients do not suggest that private firms fail to improve their carbon footprints. We only show that these improvements (if any) are unlikely a response to the stock price pressure. Private firms may still improve due to higher climate awareness and regulations (for the impact of regulations and policies on firms, see, e.g., Greenstone (2002); Hanna (2010); Shapiro and Walker (2018); He et al. (2020); Reynaert (2021); Shapiro (2021)). Our overall results highlight another important channel that affects public firms—the equity market.

public firm with private firms and make two samples more comparable using this data set. We require the matched public and private firms to be in the same country and industry and keep the three private firms whose total assets are the closest to the public firm. We examine green ratios and total assets of private carbon firms under price pressure in Panel B of Table XII. Again, the coefficients on the interaction term between *Emission* and *EMC Price Gap* are both insignificant, in contrast with the increase in green ratios and the downsizing effect for public emission firms. Our comparison using private firms confirms the impact of carbon stock devaluation.

The Internet Appendix Table IA.VI confirms that the results from the matched public firm sample are consistent with those from the full sample of public firms. Columns (1) and (2) present the results for the matched public firms without and with firm fixed effects after controlling for the natural logarithm of one plus total assets. In line with the estimates in the full sample of public firms, we find that high-emission public firms in countries with wider pricing gaps have a significantly higher *Green Ratio* than clean public firms. In columns (3) to (5), we further compare public and private firms after combining the matched samples of both public and private ones. We introduce the indicator variable *Public* for public firms and its interactions with *Emission*, *EMC Price Gap*, as well as *Emission*×*EMC Price Gap*. We focus on the triple interaction term *Public*×*Emission*×*EMC Price Gap*, which highlights the difference between public and private high-emission firms in green patenting when facing a higher price pressure on emission industries. The coefficients are significantly negative for all specifications, suggesting public high-emission firms tend to file more green patents than private high-emission firms if there is higher price pressure on emission industries from publicly traded markets.

Overall, our findings support the positive role of price pressure on high-emission industries in incentivizing public firms to become greener. With larger valuation gaps between carbon and clean industries, publicly-traded carbon firms tend to reduce carbon emission intensities in all three scopes and redirect technical change from dirty innovation toward clean innovation, although they downsize their operations at the same time. The results in the sample of private firms ensure that the documented effect comes from the equity market rather than environmental regulations, which should apply to both public and private firms.

# 6 Conclusion

Limiting future global temperature increases requires international coordination among scientists, governments, companies, and the general public. How does the financial market help? The empirical evidence on the role of investors so far focuses mostly on shareholder engagement: A survey of institutional investors (Krueger et al., 2020) finds that 43% of the respondents held discussions with portfolio companies' management regarding climate risks in the past five years. Azar et al. (2021) show that the largest institutional investors focus their engagement effort on large firms with high emissions and that the engagement influence results in lower carbon emissions.

In this paper, we follow theoretical predictions to establish the association between climate awareness and stock prices and divestment, and examine high-emission firms' real decisions under lower price valuation. While recent work (e.g., Gibson et al. (2021b); Liang et al. (2022)) points out that some institutional investors may be committing "greenwashing" and not lowering their carbon exposure, our country-level result shows that there is a shift in institutions' and retail investors' capital toward green firms. Consistent with the theoretical predictions made by Pastor et al. (2021), the positive shock in investors' climate awareness in a country is associated with lower equity prices of high-emission firms in the same country; under the price pressure, public high-emission firms lower $CO_2$ emission intensities and increase green innovation activities. We also find that these firms are more likely to downsize their operations and rely on internal financing facing a higher cost of capital.

Our comparison between public and private firms identifies the importance of the equity market. While a general increase in climate awareness may also prompt all high-emission firms to become cleaner, our evidence suggests that the stock market can amplify its impact. Using natural shocks, we show that retail investors and financial institutions divest more from high-emission stocks and stock prices of public high-emission firms fall after an increase in climate awareness. Private high-emission firms do not face divestment and price pressure directly, and we find that these firms do not show the same response in carbon footprint improvements.

# References


**Advisors, Arabella**, "The Global Fossil Fuel Divestment and Clean Energy Investment Movement," Technical Report 2018.

**Alekseev, Georgij, Stefano Giglio, Quinn Maingi, Julia Selgrad, and Johannes Stroebel**, "A quantity-based approach to constructing climate risk hedge portfolios," Technical Report, Working Paper 2021.

**Alliance, Global Sustainable Investment**, *Global Sustainable Investment Review*, 2020 ed., Global Sustainable Investment Alliance, 2020.

**Alok, Shashwat, Nitin Kumar, and Russ Wermers**, "Do fund managers misestimate climatic disaster risk," *Review of Financial Studies*, 2020, *33* (3), 1146–1183.

**Anderson, Anders and David T Robinson**, "Climate fears and the demand for green investment," *Swedish House of Finance Research Paper*, 2019, (19-14).

**Azar, José, Miguel Duro, Igor Kadach, and Gaizka Ormazabal**, "The big three and corporate carbon emissions around the world," *Journal of Financial Economics*, 2021, *142* (2), 674–696.

**Baker, Scott R., Nicholas Bloom, and Stephen Terry**, "Using Disasters to Estimate the Impact of Uncertainty," *Review of Economic Studies, accepted*, 2022.

**Boermans, Martijn A and Rients Galema**, "Are pension funds actively decarbonizing their portfolios?," *Ecological Economics*, 2019, *161*, 50–60.

**Bolton, Patrick and Marcin Kacperczyk**, "Do investors care about carbon risk?," *Journal of Financial Economics*, 2021, *142* (2), 517–549.

**Broccardo, Eleonora, Oliver Hart, and Luigi Zingales**, "Exit vs. Voice," *Journal of Political Economy*, April 2022.

**Chava, Sudheer**, "Environmental Externalities and Cost of Capital," *Management Science*, 2014, *60* (9), 2223–2247.

**Choi, Darwin, Zhenyu Gao, and Wenxi Jiang**, "Attention to global warming," *Review of Financial Studies*, 2020, *33* (3), 1112–1145.

**_ , _ , and _** , "Measuring the Carbon Exposure of Institutional Investors," *Journal of Alternative Investments*, 2020.

**Chowdhry, Bhagwan, Shaun William Davies, and Brian Waters**, "Investing for Impact," *Review of Financial Studies*, March 2019, *32* (3), 864–904.

**Cohen, Lauren, Umit G Gurun, Quoc H Nguyen et al.**, "The ESG-Innovation Disconnect: Evidence from Green Patenting," Technical Report, National Bureau of Economic Research, Inc 2020.

**Dasgupta, Sudipto, Thanh Huynh, and Ying Xia**, "Joining forces: The spillover effects of EPA enforcement actions and the role of socially responsible investors," *Review of Financial Studies*, Forthcoming.

**Dechezlepretre, Antoine, Adrien Fabre, Tobias Kruse, Bluebery Planterose, Ana Sanchez Chico, and Stefanie Stantcheva**, "Fighting Climate Change: International Attitudes Toward Climate Policies," Technical Report, Working Paper 2022.

**Dyck, Alexander, Karl V Lins, Lukas Roth, and Hannes F Wagner**, "Do institutional investors drive corporate social responsibility? International evidence," *Journal of Financial Economics*, 2019, *131* (3), 693–714.

**Fama, Eugene F and Kenneth R French**, "The cross-section of expected stock returns," *Journal of Finance*, 1992, *47* (2), 427–465.

**Gibson, Rajna, Philipp Krueger, and Shema F. Mitali**, "The sustainability footprint of institutional investors," *Swiss Finance Institute Research Paper*, 2021, (17-05).

**_ , Simon Glossner, Philipp Krueger, Pedro Matos, and Tom Steffen**, "Do Responsible Investors Invest Responsibly?," Technical Report, ECGI Working Paper Series in Finance 2021.

**Giglio, Stefano, Bryan Kelly, and Johannes Stroebel**, "Climate Finance," *Annual Review of Financial Economics*, 2021, *13* (1), 15–36.

**Golosov, Mikhail, John Hassler, Per Krusell, and Aleh Tsyvinski**, "Optimal Taxes on Fossil Fuel in General Equilibrium," *Econometrica*, 2014, *82* (1), 41–88.

**Greenstone, Michael**, "The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 clean air act amendments and the census of manufactures," *Journal of Political Economy*, 2002, *110* (6), 1175–1219.

**Hanna, Rema**, "US environmental regulation and FDI: evidence from a panel of US-based multinational firms," *American Economic Journal: Applied Economics*, 2010, *2* (3), 158–89.

**Haščič, Ivan and Mauro Migotto**, "Measuring environmental innovation using patent data," 2015.

**He, Guojun, Shaoda Wang, and Bing Zhang**, "Watering down environmental regulation in China," *Quarterly Journal of Economics*, 2020, *135* (4), 2135–2185.

**Heinkel, Robert, Alan Kraus, and Josef Zechner**, "The effect of green investment on corporate behavior," *Journal of Financial and Quantitative Analysis*, 2001, *36* (4), 431–449.

**Hirji, Zahra**, "2015: The Year Divestment Hit the Mainstream," December 2015.

**Hong, Harrison and Marcin Kacperczyk**, "The price of sin: The effects of social norms on markets," *Journal of Financial Economics*, 2009, *93* (1), 15–36.

**__ , G Andrew Karolyi, and José A Scheinkman**, "Climate Finance," *Review of Financial Studies*, March 2020, *33* (3), 1011–1023.

**__ , Neng Wang, and Jinqiang Yang**, "Welfare consequences of sustainable finance," Technical Report, National Bureau of Economic Research 2021.

**Hsu, Po-Hsuan, Kai Li, and Chi-Yang Tsou**, "The pollution premium," *Journal of Finance, forthcoming*, 2022.

**Kelly, David L. and Charles D. Kolstad**, "Bayesian learning, growth, and pollution," *Journal of Economic Dynamics and Control*, February 1999, *23* (4), 491–518.

**Koijen, Ralph SJ, Robert J Richmond, and Motohiro Yogo**, "Which investors matter for equity valuations and expected returns?," Technical Report, National Bureau of Economic Research 2020.

**Krey, Volker and Omar Masera**, "Metrics and Methodolgy," in "Climate Change 2014: Mitigation of Climate Change: Working Group III Contribution to the IPCC Fifth Assessment Report," Cambridge University Press, 2015, pp. 1281–1328.

**Krueger, Philipp, Zacharias Sautner, and Laura T Starks**, "The importance of climate risks for institutional investors," *Review of Financial Studies*, 2020, *33* (3), 1067–1111.

**__ , __ , Dragon Yongjun Tang, and Rui Zhong**, "The effects of mandatory ESG disclosure around the world," *European Corporate Governance Institute–Finance Working Paper*, 2021, (754), 21–44.

**Liang, Hao, Lin Sun, and Song Wee Melvyn TEO**, "Responsible hedge funds," *Review of Finance*, 2022, pp. 1–49.

**Nordhaus, William D.**, "Economic growth and climate: the carbon dioxide problem," *American Economic Review*, 1977, *67* (1), 341–346.

__ , "To slow or not to slow: the economics of the greenhouse effect," *Economic Journal*, 1991, *101* (407), 920–937.

__ , "An optimal transition path for controlling greenhouse gases," *Science*, 1992, *258* (5086), 1315–1319.

**Oehmke, Martin and Marcus M. Opp**, "A Theory of Socially Responsible Investment," April 2022.

**Pastor, Lubos, Robert F Stambaugh, and Lucian A Taylor**, "Sustainable Investing in Equilibrium," *Journal of Financial Economics, forthcoming*, 2021.

**__ , __ , and __** , "Dissecting green returns," Technical Report, National Bureau of Economic Research 2022.

**Reynaert, Mathias**, "Abatement strategies and the cost of environmental regulation: Emission standards on the European car market," *Review of Economic Studies*, 2021, *88* (1), 454–488.

**Rohleder, Martin, Marco Wilkens, and Jonas Zink**, "The effects of mutual fund decarbonization on stock prices and carbon emissions," *Journal of Banking and Finance*, 2022, *134*, 106352.

**Shapiro, Joseph S**, "The environmental bias of trade policy," *Quarterly Journal of Economics*, 2021, *136* (2), 831–886.

_ **and Reed Walker**, "Why is pollution from US manufacturing declining? The roles of environmental regulation, productivity, and trade," *American Economic Review*, 2018, *108* (12), 3814–54.

**Stroebel, Johannes and Jeffrey Wurgler**, "What do you think about climate finance?," *Journal of Financial Economics*, November 2021, *142* (2), 487–498.

**Weitzman, Martin L**, "On Modeling and Interpreting the Economics of Catastrophic Climate Change," *Review of Economics and Statistics*, February 2009, *91* (1), 1–19.

**Zhang, Shaojun**, "Carbon Premium: Is It There?," *Available at SSRN*, 2022.

**Table I.** List of countries

This table lists 26 countries/areas that we use in analysis and reports the average number of public firms, average number of institutions that hold the country's stocks, average institutional and retail ownership, and average *EMC Price Gaps* (defined as the value-weighted average price-to-book, price-to-sales, price-to-earnings, price-to-cashflow of emission firms net of the value-weighted average of clean firms) in each country during the sample period, from 2007Q1 to 2020Q4.

| | | | | | EMC Price Gap | | | |
|---|---|---|---|---|---|---|---|---|
| Country/Area | #Public firms | #Institutions | IO(%) | Retail Ownership(%) | PB | PS | PE | PCF |
| Australia | 1636.4 | 1246.1 | 17.2 | 75.3 | -0.776 | 0.599 | 4.405 | -3.541 |
| Austria | 67.8 | 873.8 | 16.3 | 46.5 | 0.413 | 0.834 | 0.341 | 6.977 |
| Belgium | 121.3 | 1123.5 | 16.4 | 45.6 | 0.067 | -1.200 | -6.109 | -0.021 |
| Canada | 896.4 | 3121.0 | 39.0 | 52.0 | -0.386 | 1.807 | 5.908 | -0.237 |
| China | 2412.6 | 591.9 | 9.6 | 64.3 | -1.671 | -3.357 | -2.338 | -7.703 |
| Denmark | 160.3 | 1018.7 | 30.5 | 47.3 | -6.165 | -4.203 | -7.993 | -8.926 |
| Egypt | 196.9 | 177.4 | 7.4 | 64.1 | 1.125 | 3.387 | 15.035 | 7.029 |
| Finland | 123.2 | 867.8 | 32.3 | 50.6 | -0.809 | -0.715 | -3.383 | -13.224 |
| France | 711.5 | 1901.3 | 24.1 | 53.2 | -0.127 | -1.344 | -4.742 | -3.804 |
| Germany | 320.1 | 996.9 | 14.2 | 49.4 | 0.438 | -0.228 | -7.527 | 9.611 |
| Greece | 205.3 | 482.1 | 12.0 | 60.0 | -1.118 | -0.874 | 5.765 | 1.857 |
| Hong Kong | 1579.4 | 1427.3 | 15.0 | 53.7 | -1.315 | -0.354 | -3.471 | 1.261 |
| India | 2810.1 | 680.3 | 21.7 | 38.7 | -2.147 | -0.239 | -9.058 | -3.891 |
| Israel | 385.6 | 509.5 | 8.1 | 65.5 | 0.821 | 1.162 | -2.740 | 6.624 |
| Italy | 271.2 | 1472.0 | 19.3 | 53.0 | -0.257 | -1.569 | 2.142 | -7.131 |
| Japan | 2817.3 | 1389.4 | 16.4 | 64.4 | -0.684 | -0.936 | -3.414 | -4.250 |
| Netherlands | 102.4 | 1493.9 | 29.6 | 54.0 | 0.687 | -0.003 | 4.900 | 5.174 |
| New Zealand | 117.5 | 381.1 | 16.0 | 64.2 | -1.292 | -2.392 | 3.280 | 2.078 |
| Poland | 503.4 | 425.8 | 27.1 | 48.2 | -0.401 | 0.046 | -1.658 | 0.762 |
| Singapore | 651.9 | 913.0 | 11.5 | 58.4 | -0.616 | -1.654 | 1.510 | 2.653 |
| South Africa | 295.7 | 689.7 | 24.8 | 56.4 | -1.231 | -2.338 | 1.448 | -14.309 |
| South Korea | 1722.6 | 854.7 | 18.7 | 46.3 | -1.253 | -3.211 | -10.538 | -7.928 |
| Spain | 154.9 | 1326.3 | 18.6 | 59.4 | -1.335 | 0.052 | -2.105 | 0.458 |
| Sweden | 533.1 | 1211.3 | 37.1 | 48.0 | 0.020 | -2.121 | 4.286 | -1.137 |
| United Kingdom | 1551.8 | 3364.3 | 43.5 | 49.9 | -1.157 | -0.894 | -0.892 | -3.380 |
| United States | 3964.0 | 5894.9 | 60.1 | 35.2 | -1.129 | -1.596 | -10.208 | -4.157 |
| Average | 935.1 | 1324.4 | 22.6 | 54.0 | -0.781 | -0.821 | -1.044 | -1.506 |
| #Country/Area | 26 | | | | | | | |

**Table II.** Summary statistics

This table reports summary statistics of key variables. Panel A shows the summary statistics for country-year-level variables. *EMC Price Gap (VW)* is calculated as the value-weighted average price-to-book, price-to-sales, price-to-earnings, price-to-cashflow of emission firms net of the value-weighted average of clean firms in the country/area. *EMC Price Gap (EW)* is calculated as the equal-weighted average price-to-book, price-to-sales, price-to-earnings, price-to-cashflow of emission firms net of the equal-weighted average of clean firms in the country/area. *Natural Shocks* is the number of natural shocks that happen in a country-year-quarter. *Log SVI* is the log of one plus the Google search volume index of "Climate Change" in a country-year-quarter. *Log News* is the log of one plus the number of Bloomberg news of "Climate Change" in a country-year-quarter. Panel B and C show the summary statistics for firm-year and firm-year-quarter level variables. *Log Scope1*, *Log Scope2* and *Log Scope3* represent the log of one plus the scope 1, scope 2, and scope 3 carbon emissions. *S1int*, *S2int*, and *S3int* are total scope 1, scope 2 and scope 3 $CO_2$ emissions over total sales. *Green Ratio (%)* is the proportion of green patents that the firm files in the year-quarter. *Total Patent* is the number of patent filed by each firm each year-quarter. *Log PB* to *Log PCF* are the log of one plus price-to-book, price-to-sales, price-to-earnings, and price-to-cashflow. *Log Sales* and *Log Total Assets* are the log of total revenue and total assets for the firm. *CapEx(%)* is the total capital expenditures over lagged total assets. *Payout Ratio(%)* and *Repur. Ratio(%)* are total payout(=dividend plus repurchase) and stock repurchases, divided by total earnings. *Stock Sales Rate(%)* is the new stock issuance divided by lagged market capitalization. *ST Debt(%)* and *LT Debt(%)* are net cashflows from short-term debt and long-term debt, divided by lagged total assets. *ESG Disclosure* equals one if the country-year has the ESG mandatory disclosure requirement. *Retail and Inst. Ownership (%)*, *Retail Ownership (%)*, *IO(%)* are ownership by retail and institutional investors, retail investors, and institutional investors. *IO(%)* is divided into ownership by domestic institutions *Domestic IO(%)* and foreign institutions *Foreign IO(%)*. The sample includes the 26 markets listed in Table I from 2007Q1 to 2020Q4.

*Panel A: Country-year-quarter level*

| **Variable** | **N** | **Mean** | **SD** | **P5** | **P25** | **P50** | **P75** | **P95** |
|---|---|---|---|---|---|---|---|---|
| EMC PB Gap (VW) | 1456 | -0.781 | 1.798 | -3.448 | -1.371 | -0.596 | 0.144 | 1.285 |
| EMC PS Gap (VW) | 1456 | -0.821 | 3.264 | -4.907 | -1.738 | -0.804 | 0.321 | 2.676 |
| EMC PE Gap (VW) | 1456 | -1.044 | 16.411 | -20.302 | -7.586 | -1.526 | 4.581 | 18.526 |
| EMC PCF Gap (VW) | 1456 | -1.506 | 11.176 | -16.599 | -5.319 | -0.749 | 3.697 | 11.187 |
| EMC PB Gap (EW) | 1456 | -0.648 | 0.717 | -1.851 | -1.083 | -0.599 | -0.258 | 0.441 |
| EMC PS Gap (EW) | 1456 | -1.600 | 2.341 | -5.581 | -2.852 | -1.446 | -0.356 | 2.099 |
| EMC PE Gap (EW) | 1456 | -3.312 | 10.287 | -20.099 | -9.376 | -3.530 | 2.665 | 13.268 |
| EMC PCF Gap (EW) | 1456 | -2.183 | 6.210 | -12.039 | -6.028 | -2.507 | 1.309 | 9.185 |
| Natural Shocks | 1456 | 0.424 | 0.906 | 0.000 | 0.000 | 0.000 | 0.000 | 3.000 |
| Log SVI | 1800 | 1.838 | 1.192 | 0.000 | 1.099 | 1.946 | 2.639 | 3.738 |
| Log News | 1014 | 6.291 | 1.642 | 4.205 | 5.069 | 5.936 | 7.379 | 9.479 |

*Panel B: Firm-year level*

| Variable | N | Mean | SD | P5 | P25 | P50 | P75 | P95 |
|---|---|---|---|---|---|---|---|---|
| | | | | *Public firms* | | | | |
| S1int | 74122 | 150.664 | 537.133 | 0.610 | 7.511 | 17.639 | 50.003 | 652.867 |
| S2int | 74122 | 40.070 | 67.715 | 1.793 | 9.568 | 20.990 | 47.612 | 136.699 |
| S3int | 74120 | 165.572 | 150.104 | 26.125 | 49.085 | 107.550 | 243.550 | 464.328 |
| Log Scope1 | 74122 | 9.797 | 2.798 | 5.137 | 7.971 | 9.753 | 11.607 | 14.626 |
| Log Scope2 | 74122 | 9.811 | 2.200 | 5.976 | 8.438 | 9.915 | 11.362 | 13.227 |
| Log Scope3 | 74120 | 11.529 | 2.165 | 7.848 | 10.069 | 11.639 | 13.119 | 14.849 |
| EMC Price Gap | 74122 | -1.099 | 0.927 | -2.210 | -1.684 | -1.048 | -0.570 | 0.265 |
| IO(%) | 74122 | 30.567 | 29.269 | 0.557 | 7.140 | 19.367 | 52.225 | 84.370 |
| ESG Disclosure | 74122 | 0.377 | 0.485 | 0.000 | 0.000 | 0.000 | 1.000 | 1.000 |
| Log Sales | 278793 | 4.761 | 2.327 | 0.029 | 3.354 | 4.929 | 6.363 | 8.460 |
| Log Total Assets | 281234 | 5.522 | 2.183 | 1.880 | 4.015 | 5.495 | 6.988 | 9.298 |
| CapEx (%) | 276218 | 5.086 | 6.945 | 0.003 | 0.774 | 2.765 | 6.469 | 18.744 |
| Payout Ratio (%) | 224104 | 20.107 | 24.637 | 0.000 | 0.000 | 10.753 | 33.321 | 73.024 |
| Repur. Ratio (%) | 250951 | 1.111 | 6.240 | 0.000 | 0.000 | 0.000 | 0.000 | 4.225 |
| Stock Sales Rate (%) | 267712 | 3.696 | 12.223 | 0.000 | 0.000 | 0.000 | 0.331 | 24.389 |
| ST Debt (%) | 209787 | 0.288 | 3.752 | -4.727 | 0.000 | 0.000 | 0.000 | 6.534 |
| LT Debt (%) | 277149 | 1.132 | 6.549 | -5.925 | -0.429 | 0.000 | 0.519 | 13.076 |
| | | | | *Private firms* | | | | |
| S1int | 14609 | 287.934 | 1229.942 | 0.554 | 3.870 | 20.083 | 42.024 | 1253.107 |
| S2int | 14609 | 36.959 | 120.632 | 1.023 | 7.241 | 12.328 | 33.785 | 137.122 |
| S3int | 14609 | 142.234 | 175.182 | 23.871 | 41.287 | 92.991 | 180.053 | 391.726 |
| Log Scope1 | 14609 | 9.336 | 3.321 | 3.554 | 7.451 | 9.272 | 11.340 | 15.423 |
| Log Scope2 | 14609 | 9.054 | 2.691 | 4.185 | 7.418 | 9.202 | 10.897 | 13.280 |
| Log Scope3 | 14609 | 11.042 | 2.473 | 6.645 | 9.649 | 11.119 | 12.687 | 14.836 |

*Panel C: Firm-year-quarter level*

| Variable | N | Mean | SD | P5 | P25 | P50 | P75 | P95 |
|---|---|---|---|---|---|---|---|---|
| | | | | *Public firms* | | | | |
| Green Ratio (%) | 122571 | 1.943 | 10.379 | 0.000 | 0.000 | 0.000 | 0.000 | 7.143 |
| Total Patent | 275968 | 24.992 | 197.233 | 0.000 | 0.000 | 0.000 | 5.000 | 68.000 |
| EMC Price Gap | 122571 | -0.939 | 0.766 | -2.025 | -1.469 | -0.609 | -0.451 | -0.244 |
| ESG Disclosure | 122571 | 0.312 | 0.463 | 0.000 | 0.000 | 0.000 | 1.000 | 1.000 |
| Log PB | 1192970 | 1.062 | 0.664 | 0.260 | 0.570 | 0.909 | 1.409 | 2.395 |
| Log PS | 1127356 | 1.056 | 0.909 | 0.121 | 0.379 | 0.792 | 1.472 | 2.864 |
| Log PE | 862195 | 3.061 | 1.004 | 1.627 | 2.403 | 2.939 | 3.591 | 4.975 |
| Log PCF | 858419 | 2.578 | 1.025 | 1.055 | 1.885 | 2.482 | 3.139 | 4.504 |
| Retail and Inst. Ownership (%) | 1229379 | 78.144 | 27.976 | 21.985 | 59.474 | 93.462 | 100.000 | 100.000 |
| Retail Ownership (%) | 1229379 | 62.503 | 33.074 | 5.200 | 33.371 | 66.429 | 97.706 | 100.000 |
| IO(%) | 1229379 | 15.641 | 24.731 | 0.000 | 0.000 | 3.424 | 19.879 | 75.052 |
| Domestic IO(%) | 1229379 | 12.340 | 22.546 | 0.000 | 0.000 | 1.179 | 12.289 | 68.624 |
| Foreign IO(%) | 1229379 | 3.301 | 6.936 | 0.000 | 0.000 | 0.139 | 3.550 | 16.427 |
| | | | | *Private firms* | | | | |
| Green Ratio (%) | 137597 | 2.262 | 11.397 | 0.000 | 0.000 | 0.000 | 0.000 | 9.703 |
| Log Total Assets | 137597 | 13.238 | 1.512 | 10.904 | 12.340 | 13.140 | 14.081 | 15.798 |

**Table III.** Country-level EMC Price Gap

This table presents the time trend of country-level price gaps. Panel A shows the results of regressions of *EMC Price Gap* on the continuous year-quarter variable *Trend*. *EMC Price Gap* is calculated as the value-weighted or equal-weighted average price-to-book, price-to-sales, price-to-earnings, price-to-cashflow of emission firms net of the value-weighted or equal-weighted average of clean firms in the country/area. Columns (1)–(4) in Panel A report results for value-weighted *EMC Price Gap*. Columns (5)–(8) in Panel A report results for equal-weighted *EMC Price Gap*. Panel B shows the results of regressions of value-weighted *EMC Price Gap* on the continuous year-quarter variable *Trend* for non-energy emission firms and energy firms. *EMC Price Gap* in columns (1)–(4) and columns (5)–(8) are calculated as the value-weighted average price-to-book, price-to-sales, price-to-earnings, price-to-cashflow of non-energy emission firms, energy firms net of the value-weighted average of clean firms in the country/area. Control variables are log GDP per capita, female ratio, corruption, government effectiveness, political stability, regulatory quality, rule of law, and accountability. The sample includes the 26 markets listed in Table I from 2007Q1 to 2020Q4. Standard errors are clustered by year-quarter, and reported in parentheses. $^{*}p < .1;^{**} p < .05;^{***} p < .01$.

*Panel A: Price gaps between emission and clean firms*

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Value-weighted | | | | Equal-weighted | | | |
| | PB | PS | PE | PCF | PB | PS | PE | PCF |
| Trend | -0.022*** | -0.057*** | -0.147*** | -0.139*** | -0.016*** | -0.029*** | -0.116*** | -0.075*** |
| | (0.002) | (0.006) | (0.026) | (0.020) | (0.001) | (0.004) | (0.020) | (0.008) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1456 | 1456 | 1456 | 1456 | 1456 | 1456 | 1456 | 1456 |
| Adj. $R^2$ | 0.622 | 0.338 | 0.147 | 0.323 | 0.510 | 0.422 | 0.271 | 0.407 |

*Panel B: Price gaps between non-energy emission, energy and clean firms*

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Non-energy emission vs. clean firms | | | | Energy vs. clean firms | | | |
| | PB | PS | PE | PCF | PB | PS | PE | PCF |
| Trend | -0.021*** | -0.057*** | -0.206*** | -0.121*** | -0.031*** | -0.072*** | 0.059 | -0.236*** |
| | (0.002) | (0.006) | (0.027) | (0.021) | (0.003) | (0.007) | (0.036) | (0.029) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1456 | 1456 | 1456 | 1456 | 1456 | 1456 | 1456 | 1456 |
| Adj. $R^2$ | 0.627 | 0.343 | 0.175 | 0.326 | 0.433 | 0.325 | 0.096 | 0.277 |

**Table IV.** Trends of firm-level prices

This table presents the trends of price ratios for emission vs. clean firms. The price ratios are *Log PB* in columns (1)–(3), *Log PS* in columns (4)–(6), *Log PE* in columns (7)–(9), and *Log PCF* in columns (10)–(12). *Emission* is an indicator of high-emission industries based on IPCC's categorization. Control variables consist of *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. The sample includes the 26 markets listed in Table I from 2007Q1 to 2020Q4. Standard errors are clustered by firm and by year-quarter, and reported in parentheses. $^{*}p < .1;^{**} p < .05;^{***} p < .01$.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Log PB | | | Log PS | | | Log PE | | | Log PCF | | |
| Emission | -0.115*** | | | -0.152*** | | | -0.123*** | | | -0.132*** | | |
| | (0.009) | | | (0.012) | | | (0.011) | | | (0.012) | | |
| Emission×Trend | | -0.002*** | -0.002*** | | -0.002*** | -0.002*** | | -0.002*** | -0.002*** | | -0.003*** | -0.003*** |
| | | (0.000) | (0.000) | | (0.000) | (0.000) | | (0.000) | (0.000) | | (0.000) | (0.000) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Quarter FE | Yes | Yes | | Yes | Yes | | Yes | Yes | | Yes | Yes | |
| Country FE | Yes | | | Yes | | | Yes | | | Yes | | |
| Firm FE | | Yes | Yes | | Yes | Yes | | Yes | Yes | | Yes | Yes |
| Country×Year-Quarter FE | | | Yes | | | Yes | | | Yes | | | Yes |
| Obs. | 1192970 | 1192213 | 1192213 | 1158743 | 1158001 | 1158001 | 873471 | 872701 | 872701 | 874959 | 874169 | 874169 |
| Adj. $R^2$ | 0.217 | 0.674 | 0.697 | 0.212 | 0.762 | 0.773 | 0.231 | 0.563 | 0.580 | 0.179 | 0.527 | 0.541 |

**Table V.** Trends of institutional and retail ownership

This table presents the trends of institutional and retail ownership for emission vs. clean firms. *Retail and Inst. Ownership (%)*, *Retail Ownership (%)*, *IO(%)* are ownership by retail and institutional investors, retail investors, and institutional investors. *IO(%)* is divided into ownership by domestic institutions *Domestic IO(%)* and foreign institutions *Foreign IO(%)*. *Emission* is an indicator of high-emission industries based on IPCC's categorization. Control variables consist of *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. The sample includes the 26 markets listed in Table I from 2007Q1 to 2020Q4. Standard errors are clustered by firm and by year-quarter, and reported in parentheses. $^{*}p < .1;^{**}p < .05;^{***}p < .01$.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Retail and Inst. Ownership(%) | | Retail Ownership(%) | IO(%) | Domestic IO(%) | Foreign IO(%) |
| Emission×Trend | -0.044*** | -0.023** | -0.011 | -0.011** | -0.008* | -0.003 |
| | (0.009) | (0.010) | (0.011) | (0.005) | (0.005) | (0.002) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Quarter FE | Yes | | | | | |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Country×Year-Quarter | | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1229379 | 1229379 | 1229379 | 1229379 | 1229379 | 1229379 |
| Adj. $R^2$ | 0.613 | 0.622 | 0.694 | 0.852 | 0.850 | 0.743 |

**Table VI.** Google search and Bloomberg news of "Climate Change" and natural disasters

This table presents the results of regressing the Google search volume index and Bloomberg news of "Climate Change" on the number of natural shocks. *Log SVI* is the log of one plus the Google search volume index of "Climate Change" in a country-year-quarter. *Log News* is the log of one plus the number of Bloomberg news of "Climate Change" in a country-year-quarter. *Natural Shocks* is the number of natural shocks that happen in a country-year-quarter. The sample in columns (1)–(2) includes the 26 markets except China listed in Table I from 2004Q1 to 2021Q4. The sample in columns (3)–(4) includes the 26 markets listed in Table I from 2012Q2 to 2021Q4. Standard errors are clustered by year-quarter, and reported in parentheses. $^{*}p < .1;^{**}p < .05;^{***}p < .01$.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Log SVI | | Log News | |
| Natural Shocks | $0.206^{***}$ | $0.063^{**}$ | $0.395^{***}$ | $0.041^{*}$ |
| | (0.031) | (0.025) | (0.054) | (0.022) |
| Year-Quarter FE | Yes | Yes | Yes | Yes |
| Country FE | | Yes | | Yes |
| Obs. | 1800 | 1800 | 1014 | 1014 |
| Adj. $R^2$ | 0.20 | 0.77 | 0.08 | 0.90 |

**Table VII.** Prices and natural disasters

This table presents the results of regressing price ratios on *Natural Shocks*. Price ratios are logs of one plus price-to-book, price-to-sales, price-to-earnings, and pricing-to-cashflows. *Emission* is an indicator of high-emission industries based on IPCC's categorization. *Natural Shocks* is the number of natural shocks that happen in a country-year-quarter. Control variables consist of *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. The sample includes the 26 markets listed in Table I from 2007Q1 to 2020Q4. Standard errors are clustered by firm and by year-quarter, and reported in parentheses. $^{*}p < .1;^{**}p < .05;^{***}p < .01$.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Log PB | | | Log PS | | | Log PE | | | Log PCF | | |
| Natural Shocks | 0.013 | | | 0.014 | | | -0.001 | | | 0.021 | | |
| | (0.012) | | | (0.012) | | | (0.013) | | | (0.013) | | |
| Emission×Natural Shocks | -0.016*** | -0.010*** | -0.018*** | -0.015*** | -0.007* | -0.012*** | -0.021*** | -0.012** | -0.013 | -0.012** | -0.008 | -0.012** |
| | (0.003) | (0.003) | (0.003) | (0.004) | (0.004) | (0.004) | (0.008) | (0.006) | (0.008) | (0.005) | (0.005) | (0.006) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | | | |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Quarter FE | Yes | | | Yes | | | Yes | | | Yes | | |
| Country×Year-Quarter FE | | Yes | Yes | | Yes | Yes | | Yes | Yes | | Yes | Yes |
| Emission×Year-Quarter FE | | | Yes | | | Yes | | | Yes | | | Yes |
| Obs. | 1192213 | 1192213 | 1192213 | 1158001 | 1158001 | 1158001 | 872701 | 872701 | 872701 | 874169 | 874169 | 874169 |
| Adj. $R^2$ | 0.674 | 0.696 | 0.697 | 0.762 | 0.773 | 0.773 | 0.563 | 0.580 | 0.580 | 0.527 | 0.541 | 0.541 |

**Table VIII.** Institutional and retail ownership and natural disasters

This table presents the results of regressing ownership on *Natural Shocks*. *Retail and Inst. Ownership (%)*, *Retail Ownership (%)*, *IO(%)* are ownership by retail and institutional investors, retail investors, and institutional investors. *IO(%)* is divided into ownership by domestic institutions *Domestic IO(%)* and foreign institutions *Foreign IO(%)*. *Emission* is an indicator of high-emission industries based on IPCC's categorization. *Natural Shocks* is the number of natural shocks that happen in a country-year-quarter. Control variables consist of *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. The sample includes the 26 markets listed in Table I from 2007Q1 to 2020Q4. Standard errors are clustered by firm and by year-quarter, and reported in parentheses. $^{*}p < .1$;$^{**}p < .05$;$^{***}p < .01$.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | Retail and Inst. Ownership(%) | | | Retail Ownership(%) | IO(%) | Domestic IO(%) | Foreign IO(%) |
| Natural Shocks | -0.106 | | | | | | |
| | (0.161) | | | | | | |
| Emission×Natural Shocks | -0.536$^{***}$ | -0.548$^{***}$ | -0.436$^{***}$ | -0.380$^{***}$ | -0.168$^{***}$ | -0.136$^{***}$ | -0.032$^{*}$ |
| | (0.119) | (0.115) | (0.144) | (0.124) | (0.051) | (0.044) | (0.017) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Quarter FE | Yes | | | | | | |
| Country×Year-Quarter FE | | Yes | Yes | Yes | Yes | Yes | Yes |
| Emission×Year-Quarter FE | | | Yes | | | | |
| Obs. | 1229379 | 1229379 | 1229379 | 1229379 | 1229379 | 1229379 | 1229379 |
| Adj. $R^2$ | 0.613 | 0.622 | 0.622 | 0.694 | 0.851 | 0.850 | 0.743 |

**Table IX.** $CO_2$ emission intensity and price gaps: Public firms

This table presents the results of regressing $CO_2$ emission intensity by public firms on price gaps. *EMC Price Gap* is value-weighted average price-to-book gap between emission and clean firms over the past year in the country/area. *S1int*, *S2int*, and *S3int* are total scope 1, scope 2 and scope 3 $CO_2$ emissions over total sales. *Emission* is an indicator of high-emission industries based on IPCC's categorization. *IO(%)* is the ownership by institutional investors. *ESG Disclosure* equals one if the country-year has the ESG mandatory disclosure requirement. Control variables consist of firm-level price-to-book ratio, *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. The sample includes the 26 markets listed in Table I from 2007 to 2020. Standard errors are clustered by firm, and reported in parentheses. $^{*}p < .1;^{**} p < .05;^{***} p < .01$.

| | (1) | (2) | (3) |
|---|---|---|---|
| | S1int | S2int | S3int |
| Emission×EMC Price Gap | 8.636** | 0.938 | 4.276*** |
| | (3.729) | (0.964) | (0.767) |
| IO(%) | 0.030 | 0.009 | 0.021 |
| | (0.086) | (0.014) | (0.015) |
| Emission×IO(%) | 0.288 | -0.009 | -0.072** |
| | (0.294) | (0.026) | (0.032) |
| Emission×ESG Disclosure | -104.168*** | 0.152 | -2.874 |
| | (29.734) | (2.849) | (3.364) |
| Controls | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes |
| Country×Year FE | Yes | Yes | Yes |
| Obs. | 74122 | 74122 | 74120 |
| Adj. $R^2$ | 0.851 | 0.841 | 0.957 |

**Table X.** Green patents and price gaps: Public firms

This table reports the regression results of green patents on price gaps for public firms. *EMC Price Gap* is the value-weighted average price-to-book gap between emission and clean firms over the past twelve quarters in the country/area. *Green Ratio (%)* is the proportion of green patents that the firm files in the year-quarter. *Emission* is an indicator of high-emission industries based on IPCC's categorization. *IO(%)* is the ownership by institutional investors. *ESG Disclosure* equals one if the country-year-quarter has the ESG mandatory disclosure requirement. *Public* equals one if the firm is listed. The control variables consist of firm-level *PB*, *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. The sample includes the 26 markets listed in Table I from 2007Q1 to 2019Q4. Standard errors are clustered by firm and by year-quarter, and reported in parentheses. $^{*}p < .1$;$^{**}p < .05$;$^{***}p < .01$.

| Dep. Var.: Green Ratio (%) | (1) | (2) | (3) |
|---|---|---|---|
| Emission | 1.123$^{***}$ | | |
| | (0.183) | | |
| EMC Price Gap | -0.144$^{*}$ | | |
| | (0.072) | | |
| Emission×EMC Price Gap | -0.297$^{**}$ | -0.312$^{**}$ | -0.310$^{**}$ |
| | (0.141) | (0.142) | (0.140) |
| IO(%) | | | 0.008$^{**}$ |
| | | | (0.003) |
| Emission×IO(%) | | | -0.006 |
| | | | (0.005) |
| Emission×ESG Disclosure | | | 0.326 |
| | | | (0.779) |
| Controls | Yes | Yes | Yes |
| Year-Quarter FE | Yes | | |
| Firm FE | | Yes | Yes |
| Country×Year-Quarter FE | | Yes | Yes |
| Obs. | 122571 | 120666 | 120666 |
| Adj. $R^2$ | 0.008 | 0.313 | 0.313 |

**Table XI.** Firm size and price gaps: Public firms

This table reports the regression results of the firm's sales, total assets, capital expenditure, payout policy, external financing, $CO_2$ emissions and total patents on price gaps for public firms. *EMC Price Gap* is the value-weighted average price-to-book gap between emission and clean firms in the country/area. *Log Sales* and *Log Total Assets* are the log of total revenue and total assets for the firm. *CapEx(%)* is the total capital expenditures over lagged total assets. *Payout Ratio(%)* and *Repur. Ratio(%)* are total payout(=dividend plus repurchase) and stock repurchases, divided by total earnings. *Stock Sales Rate(%)* is the new stock issuance divided by lagged market capitalization. *ST Debt(%)* and *LT Debt(%)* are net cashflows from short-term debt and long-term debt, divided by lagged total assets. *Log Scope1*, *Log Scope2*, and *Log Scope3* are the log of one plus total scope one, scope two, scope three $CO_2$ emissions. *Total Patent* is the number of patent filed by each firm each quarter. *Emission* is an indicator of high-emission industries based on IPCC's categorization. *IO(%)* is the ownership by institutional investors. *ESG Disclosure* equals one if the country-year-quarter has the ESG mandatory disclosure requirement. Control variables include firm-level *PB*, *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. Columns (1) and (2) do not control *Log Total Assets*. The sample includes the 26 markets listed in Table I from 2007 to 2020. Standard errors are clustered by firm and by year-quarter in column (7) and clustered by firm in other columns. Standard errors are reported in parentheses. $^{*}p < .1;^{**}p < .05;^{***}p < .01$.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Log Sales | Log Total Assets | CapEx(%) | Log Scope1 | Log Scope2 | Log Scope3 | Total Patent | Payout Ratio(%) | Repur. Ratio(%) | Stock Sales Rate(%) | ST Debt(%) | LT Debt(%) |
| Emission×EMC Price Gap | 0.024*** | 0.041*** | 0.159*** | 0.033** | 0.025** | 0.044*** | 3.985* | 0.051 | -0.109*** | 0.191*** | 0.005 | -0.020 |
| | (0.005) | (0.004) | (0.042) | (0.014) | (0.012) | (0.008) | (2.051) | (0.121) | (0.033) | (0.069) | (0.024) | (0.039) |
| IO(%) | 0.004*** | 0.005*** | 0.011*** | -0.000 | -0.000 | -0.000 | -0.010 | 0.017*** | 0.012*** | -0.006* | 0.003** | 0.005** |
| | (0.000) | (0.000) | (0.002) | (0.001) | (0.000) | (0.000) | (0.025) | (0.006) | (0.004) | (0.004) | (0.001) | (0.002) |
| Emission×IO(%) | 0.000 | -0.001 | 0.001 | 0.001 | 0.000 | 0.000 | -0.049 | -0.010 | -0.006 | -0.002 | -0.001 | -0.000 |
| | (0.001) | (0.001) | (0.003) | (0.001) | (0.001) | (0.000) | (0.053) | (0.009) | (0.006) | (0.005) | (0.002) | (0.003) |
| Emission×ESG Disclosure | -0.012 | 0.003 | -0.761*** | 0.076 | -0.042 | -0.113*** | -0.356 | 0.432 | -0.099 | 0.121 | -0.131* | -0.763*** |
| | (0.019) | (0.015) | (0.121) | (0.072) | (0.072) | (0.039) | (3.080) | (0.374) | (0.109) | (0.198) | (0.079) | (0.117) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country×Year FE | Yes | Yes | Yes | Yes | Yes | Yes | | Yes | Yes | Yes | Yes | Yes |
| Country×Year-Quarter FE | | | | | | | Yes | | | | | |
| Obs. | 280605 | 281234 | 276041 | 74122 | 74122 | 74120 | 275968 | 222710 | 250295 | 267376 | 208229 | 277301 |
| Adj. $R^2$ | 0.945 | 0.961 | 0.442 | 0.945 | 0.926 | 0.970 | 0.760 | 0.627 | 0.246 | 0.251 | 0.043 | 0.122 |

**Table XII.** $CO_2$ emission, green patent, firm size and price gaps: Private firms

This table reports the regression results of $CO_2$ emission, green patents, and firm's total assets on price gaps for private firms. Panel A reports $CO_2$ emissions by private firms. Panel B reports green patents and total assets for the matched private firms. *EMC Price Gap* is the value-weighted average price-to-book gap between emission and clean firms in the country/area. *Log Scope1*, *Log Scope2*, and *Log Scope3* are the log of one plus total scope one, scope two, scope three $CO_2$ emissions. *S1int*, *S2int*, and *S3int* are total scope 1, scope 2 and scope 3 $CO_2$ emissions over total sales. *Green Ratio (%)* is the proportion of green patents that the firm files in the year-quarter. *Log Total Assets* is the log of total assets for the firm. *Emission* is an indicator of high-emission industries based on IPCC's categorization. Column (1) of Panel B controls *Log Total Assets*. The sample includes the 26 markets listed in Table I. In Panel A, the sample period is from from 2007 to 2020 and standard errors are clustered by firm. In Panel B, the sample period is from 2011Q1 to 2018Q4 and standard errors are clustered by firm and by year-quarter. Standard errors are reported in parentheses. $^{*}p < .1;^{**} p < .05;^{***} p < .01$.

Panel A: $CO_2$ emissions

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | S1int | S2int | S3int | Log Scope1 | Log Scope2 | Log Scope3 |
| Emission×EMC Price Gap | 14.698 | -6.795* | 2.041 | -0.112** | -0.055 | -0.026 |
| | (21.849) | (3.761) | (1.520) | (0.049) | (0.055) | (0.037) |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Country×Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 14609 | 14609 | 14609 | 14609 | 14609 | 14609 |
| Adj. $R^2$ | 0.796 | 0.789 | 0.974 | 0.962 | 0.948 | 0.966 |

Panel B: Green patents and total assets

| | (1) | (2) |
|---|---|---|
| | Green Ratio (%) | Log Total Assets |
| Emission×EMC Price Gap | 0.228 | 0.030 |
| | (0.279) | (0.023) |
| Controls | Yes | |
| Firm FE | Yes | Yes |
| Country×Year-Quarter FE | Yes | Yes |
| Obs. | 137597 | 137597 |
| Adj. $R^2$ | 0.499 | 0.988 |

**Figure I.** Time trend of price-to-book ratios

This figure plots the average price-to-book ratio and gap between emission vs. clean firms of the 26 markets listed in Table I from 2007 to 2020. For each month, the value-weighted average of price-to-book of emission firms and clean firms are plotted. *PB Gap* is calculated as the value-weighted average of price-to-book of emission firms net of the value-weighted average of clean firms.

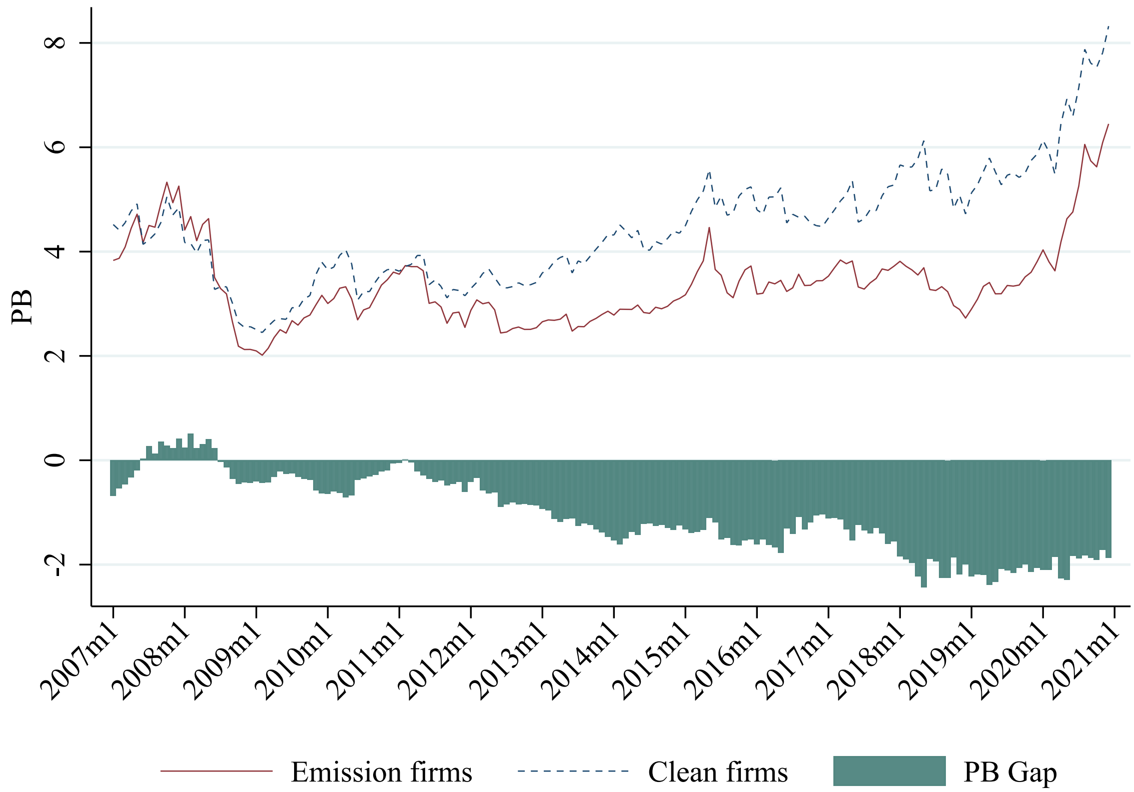
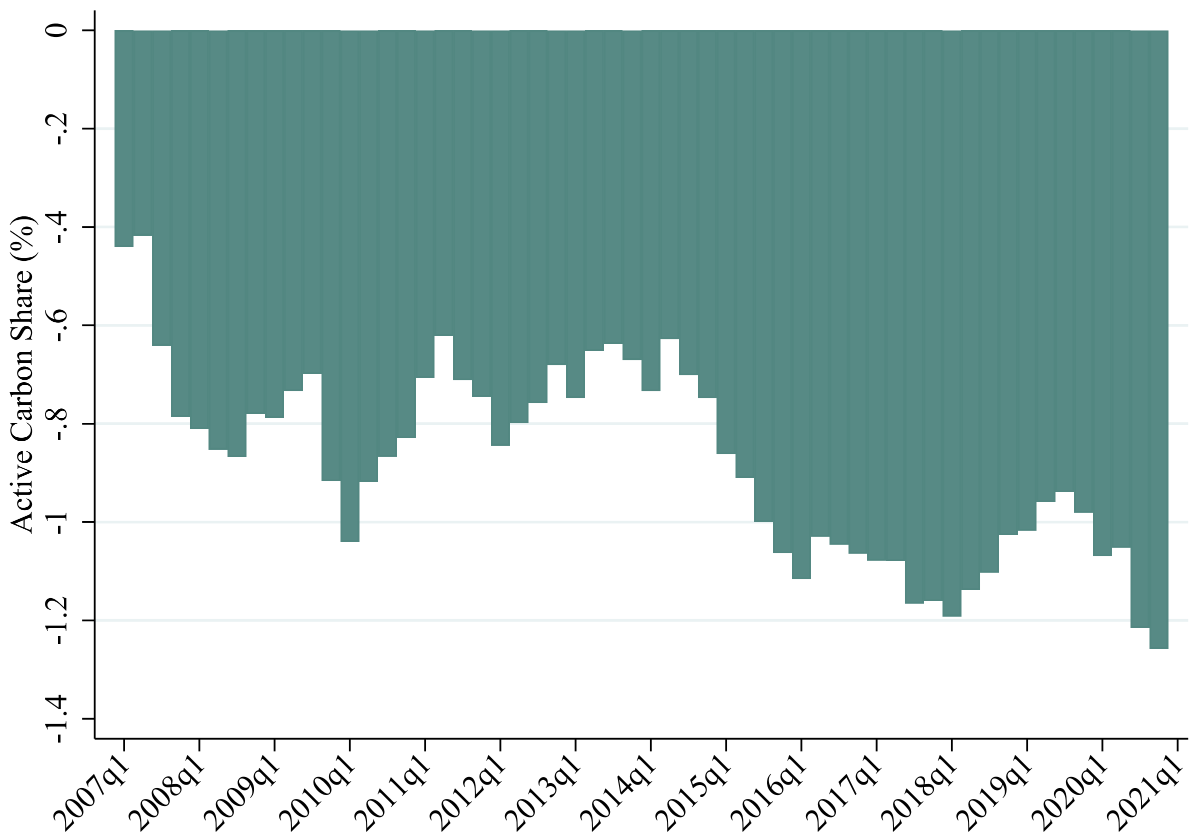


**Figure II.** Time trend of active carbon share

This figure plots the average *Active Carbon Share* of the 26 markets listed in Table I from 2007Q1 to 2020Q4. For each country/area, *Active Carbon Share* is calculated as the value-weighted average of institution and retail investors portfolio weight on emission firms net of the market weight on emission firms.



# Internet Appendix for
# "Carbon Stock Devaluation"

Darwin Choi, Zhenyu Gao, Wenxi Jiang, and Hulai Zhang

We provide additional information on portfolio holdings and fundamental variable constructions, as well as robustness tests in this internet appendix.

Section IA.1 describes the construction of portfolio holdings by institutions and blockholders from FactSet Ownership v5.

Section IA.2 illustrates additional variable definitions and data sources.

Section IA.3 gives emission industry maps and reports robustness regression results.

## IA.1 Global equity holdings

We construct a panel of quarterly equity holdings of public companies for institutional investors and blockholders. Holdings data are from FactSet Ownership v5, which includes four main tables: 13F holdings (13F: own_inst_13f_detail_eq), fund level holdings (SOF: own_fund_detail_eq), institutional stakes holdings (INST: own_inst_stakes_detail_eq), and non-institutional stakes holdings (NINST: own_stakes_detail_eq). Some countries have very few public firms (e.g., less than 50 stocks) or have very few institutions holding these stocks (e.g., less than 50 institutions). We thus restrict our sample to 26 main markets that have ample public firms and institutions holding their stocks. These main countries are Australia, Austria, Belgium, Canada, China, Denmark, Egypt, Finland, France, Germany, Greece, Hong Kong, India, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Poland, Singapore, South Africa, Spain, Sweden, United Kingdom, and United States.

We source institutional equity holdings from 13F, SOF, and INST, and non-institutional holdings from NINST.

1. 13F. These data are from mandatory 13F reports on US-traded equities held by institutions that manage more than $100 million in 13F securities.

2. SOF. These fund-level data are from SEC mandatory reports in the US and from FactSet direct collections from fund managers in other countries. We aggregate fund-level holdings to the institution level by mapping factset_fund_id to factset_inst_entity_id in own_ent_funds.

3. INST. These institutional stakes data are from several sources such as regulatory filings, company reports, etc. Institutional stakes holding for the UK are from share registers (UKSR) and regulatory news service filings (RNS). Institutional stakes holding for the US are from 13D, 13G, 13K, and proxies. For other countries, FactSet collects data from various regulatory filings. INST could be regarded as data from alternative sources other than 13F and SOF.

4. NINST. This table reports holdings from non-institutional stakeholders, and people that are identified as stakeholders. It contains duplicating institutional holdings from the previous three datasets. Thus in this table, we drop holdings of institutions in the previous three datasets.

Since institutions may not report their holdings every quarter, we interpolate their holdings using positions from the last available quarter prior to the perspective quarter. For example, if the institution reports holdings in quarter $t$ and quarter $t+2$ but missing reports in quarter $t+1$, we will interpolate their positions in quarter $t+1$ using the holdings in quarter $t$.

We combine institutional holdings and non-institutional stake holdings using the following rules.

1. UK securities. For UK securities (fds_uksr_flag=1), select UKSR and RNS positions (source_code="W" or "Q") from INST. Duplicates are removed within each institution-security-year-quarter.

2. 13F securities in US/Canada&13F institutions. For 13F securities (fds_13f_flag=1 or fds_13f_ca_flag=1) and 13F institutions (fds_13f_flag=1), select holdings from 13F.

Unless there are no records in 13F, use INST and SOF. Duplicates are removed within each institution-security-year-quarter.

3. 13F securities in US/Canada&non-13F institutions. For 13F securities (fds_13f_flag=1 or fds_13f_ca_flag=1) and non-13F institutions (fds_13f_flag=0), select holdings from INST. Unless there are no records in INST, use 13F and SOF. Duplicates are removed within each institution-security-year-quarter.

4. non-13F securities&non-UK securities. For non-13F securities and non-UK securities (fds_13f_flag=0 and fds_13f_ca_flag=0 and fds_uksr_flag=0), select holdings from INST, SOF, and 13F. Duplicates are removed within each institution-security-year-quarter.

5. Select non-institutional stake holdings from NINST. Remove duplicating holdings of institutions in 13F, SOF, and INST.

We merge on security prices from own_sec_prices_eq in FactSet Ownership v5 and calculate the dollar value of holdings. Prices are adjusted for company operations such as splits. Occasionally, the dollar holding of a given security by one entity is greater than the market cap of the security. We drop the holding in this case.

We restrict holdings to common equity and depositary receipts: sym_coverage.fref_security_type are among "SHARE", "ADR", "DR", "GDR", and "NVDR".

## IA.2 Variable Definitions and Data Sources

Data on market capitalization and fundamentals are from FactSet Fundamentals North America v3 and Fundamentals International v3. We select one security for each company which is uniquely identified: ff_sec_coverage.ff_iscomp=1.

Market capitalization. We get the monthly security prices and shares outstanding from cs3_monthly_prices_final_usc and cs3_monthly_prices_final_int. Prices and shares outstanding are adjusted for company operations such as splits before calculating the market capitalization. We convert market capitalization to USD using the point-in-time exchange rates in fx_rates_usd.

Fundamentals. We combine 12 files from FactSet Fundamentals v3: basic_X, basic_der_X, advanced_X, advanced_der_X, where X stands for three regions "am", "ap", and "eu." We convert fundamentals to USD using the point-in-time exchange rates in fx_rates_usd. We construct firm-level fundamentals following the procedure in Fama and French (1992). We assume the lag of six months before the fundamentals get public.

- Log Total Assets. This is defined as the log of one plus total assets (=log(ff_assets+1)).
- Log Sales. This is the log of total revenue of the firm (=log(ff_sales+1)).
- Book Equity. Book equity is shareholder equity plus deferred taxes and investment tax credit, minus preferred stock (=ff_shldrs_eq+ff_dfd_tax_itc-ff_pfd_stk). We regard deferred taxes and investment tax credit, and preferred stock as zero if they are missing.
- PB. Price-to-book is defined as market cap divided by book equity.
- PS. Price-to-sales is calculated by market cap divided by total sales (=MktCap/ff_sales).
- PE. Price-to-earnings is calculated by market cap divided by total income before extraordinary items (=MktCap/ff_net_inc_basic_beft_xord).
- PCF. Price-to-cashflow is calculated by market cap divided by net cashflow. Net cashflow equals funds from operations plus extraordinary item, plus changes in working capital (=ff_funds_oper_gross+ff_xord_cf+ff_wkcap_chg). We regard extraordinary item and changes in working capital as zero if they are missing.
- Book Leverage. It is defined as total debt over total assets (=ff_debt/ff_assets).

- Cash/Total Assets. It is calculated as total cash and equivalents divided by total assets (=ff_cash_generic/ff_assets).

- ROE. ROE is calculated as net income minus discontinued operations, divided by shareholder equity (=(ff_net_income-ff_disc_oper)/[(ff_shldrs_eq+L.ff_shldrs_eq)/2]).

- CapEx(%). It is the total capital expenditures over lagged total assets.

- Payout Ratio(%). It represent total dividend(=ff_div_cf) and repurchase(=ff_stk_purch_cf) payouts, divided by total earnings(=ff_shldrs_eq×ff_eps).

- Repurchase Ratio(%). It represents the payment for stock repurchases (=ff_stk_purch_cf), divided by total earnings(=ff_shldrs_eq×ff_eps).

- Stock Sales Rate(%). This gives the cash flow from selling stocks (ff_stk_sale_cf), divided by lagged market cap.

- LT Debt CF. It represents the net cashflow from long-term debt. It is calculated as the long-term borrowings (ff_debt_lt_iss_cf) minus reduction in long-term debt (ff_debt_lt_reduct_cf).

- ST Debt CF. It represents the net cashflow from short-term debt. It is calculated as the short-term borrowings (ff_debt_st_iss_cf) minus reduction in short-term debt (ff_debt_st_reduct_cf).

- LT Debt(%). It is defined as LT Debt CF over lagged total assets.

- ST Debt(%). It is defined as ST Debt CF over lagged total assets.

We get firm's industry information from sym_entity_sector.industry_code in FactSet and NACE Rev. 2 in BvD Orbis.

We collect climate news from RepRisk. RepRisk provides detailed information about each piece of news, including its novelty, severity, and influence. RepRisk also has information about which company each incidence is linked to. In our paper, we keep all environment related incidences (environment = "T") with medium or high severity (severity = 2 or 3) and with novelty (novelty = 2).

We collect country level demographic and economic data from World Bank.

- GDP per capita. GDP per capita is gross domestic product over midyear population.
- Female ratio. It measures the share of female population in each country.
- Corruption. Control of corruption measures the degree of country power that prevents the abuse of public office for private gain. Coded from -2.5 (weak) to +2.5 (strong).
- Government effectiveness. It measures the extent of the quality of public services and civil service, independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to policies. Coded from -2.5 (weak) to +2.5 (strong).
- Political stability. This measures the likelihood of political instability and politically-motivated violence such as terrorism. Coded from -2.5 (weak) to +2.5 (strong).
- Regulatory quality. This measures the government's ability to formulate and implement strong policies and regulations that promote private sector development. Coded from -2.5 (weak) to +2.5 (strong).
- Rule of law. This measures the extent to which agents have confidence in the rules of society, especially the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. Coded from -2.5 (weak) to +2.5 (strong).
- Accountability. Voice and accountability measures the degree to which citizens can participate in selecting their government, also the free expression, free association, and free media. Coded from -2.5 (weak) to +2.5 (strong).

## IA.3 Emission industry maps and robustness tests

Table IA.I provides a map between FactSet industry groups, NAVE Rev. 2 industry categories, and industries identified as major emission sources by the Inter-governmental Panel on Climate Change (IPCC). The full list of IPCC Category Codes can be found in Annex II of the IPCC's Fifth Assessment Report, issued in 2014 (Krey and Masera (2015), P.1302–1304). We obtain industry information on firms from FactSet and BvD Orbis and classify firms as high-emissions if they belong to industries in this table.

Table IA.II presents the time trend of country-level price gaps. In Panel A, emission firms are determined by their $CO_2$ intensities: the sum of scope 1, 2, and 3 emissions over sales. When a firm's $CO_2$ intensity is among the top 30% in the country-year-quarter, the firm is regarded as a high emission firm. When a firm's $CO_2$ intensity is among the bottom 30% in the country-year-quarter, the firm is regarded as a low emission firm. While in Panel B, emission firms are determined by negative environmental news coverage. A firm is regarded as an emission firm if it has been covered by negative environmental news in the past twelve months, and as a clean firm otherwise.

Table IA.III presents the trends of price ratios for emission vs. clean firms. Instead of using continuous year-quarter variable *Trend*, this table uses year dummies and compares price ratios each year with the one in $Year == 2007$.

Table IA.IV presents the trends of institutional and retail ownership for emission vs. clean firms. Instead of using continuous year-quarter variable *Trend*, this table uses year dummies and compares institutional and retail ownership each year with the one in $Year == 2007$.

Table IA.V presents the regressions of $CO_2$ emission intensity and total $CO_2$ emission by public firms on price gaps. Rather than using price-to-book to calculate *EMC Price Gap*, *EMC Price Gap* in Table IA.V is the value-weighted average price-to-sales, price-to-earnings, and price-to-cashflows of emission firms net of the value-weighted average of clean firms in the country/area. Panel A reports results for $CO_2$ emission intensity. Panel B reports total $CO_2$ emission.

Table IA.VI compares the green innovations between public and private firms. It shows how green patents by the matched public firms react to *EMC Price Gap*, as well as how public and private firms react differently to *EMC Price Gap*. *EMC Price Gap* is defined as value-weighted price-to-book gap over the past twelve or four quarters in the country/area.

**Table IA.I.** Summary of industry information

This table maps emission industries according to FactSet, NACE Rev. 2, and the IPCC.

| FactSet code | NACE | IPCC category code | IPCC industry name |
|---|---|---|---|
| *Energy* | | | |
| 2125 | 05 | 1A2f4 | Mining and quarrying |
| 1235 | | 1A1a | Power and Heat Generation |
| 2105, 3105 | 06 | 1B2 | Flaring and fugitive emissions from oil and Natural Gas |
| 3130, 4735 | | 1A3e, 1B2 | Non-road transport (fossil), Flaring and fugitive emissions from oil and Natural Gas |
| 2110, 2120, 3110 | | 1A1bc | Other Energy Industries |
| *Transport* | | | |
| 1330, 4605, 4610 | 51 | 1A3a, 1C1 | Domestic air transport, International aviation |
| 4625 | 49, 50 | 1A3d, 1C2 | Inland shipping (fossil), International navigation |
| 4620 | | 1A3c | Rail transport |
| 4630 | 52 | 1A2f2, 1A3b | Transport equipment, Road transport (includes evaporation) (fossil) |
| 4615 | | 1A3b | Road transport (includes evaporation) (fossil) |
| *Buildings* | | | |
| 1135, 1230 | 43 | 1A4a, 2A1 | Commercial and public services (fossil), Cement production |
| 1220, 3115 | 41 | 1A2f6 | Construction |
| 1415, 4885 | 42 | 1A4b | Residential (fossil) |
| *Industry* | | | |
| 1115 | | 1A2b, 2C3 | Non-ferrous metals, Aluminum production (primary), |
| 1225, 1405 | 29, 30 | 1A2f2 | Transport equipment |
| 2205, 2210, 2215 | 19, 20, 22, 23 | 1A2c | Chemicals |
| 1310, 1315, 1320, 1340, 1355 | 27 | 2F7a, 2F8a | Semiconductor Manufacture, Electrical Equipment Manufacture |
| 1125 | 07, 08, 09 | 1A2f4 | Mining and quarrying |
| 1210 | 28, 33 | 1A2f3 | Machinery |
| 1105 | | 1A2a | Iron and steel |
| 1425, 1430, 2220, 1130, 4705, 4755 | 02, 13, 16, 35, 36 | 1A1a, 1A2f | Power and Heat Generation, Other industries (stationary) (fossil) |
| 1120 | 24 | 1A2b | Non-ferrous metals |
| 2230 | 17 | 1A2d | Pulp and paper |
| 1205 | 25 | 2Cr | Non-ferrous metals production |
| 1305 | 26 | 2F7a | Semiconductor Manufacture |
| 2405, 2410, 2415, 2430 | 10, 12 | 1A2e | Food and tobacco |
| | 37, 38, 39 | 6A | Solid waste disposal on land |
| *AFOLU* | | | |
| 2225 | 01, 03 | 1A4c3, 4A, 4B, 4C, 4Dr | Fishing (fossil), Enteric Fermentation, Manure management, Rice cultivation, Agricultural soils (direct) |

**Table IA.II.** Country-level EMC Price Gap

This table presents the time trend of country-level price gaps. Panel A shows the results of regressing *EMC Price Gap* on continuous year-quarter variable *Trend*. *EMC Price Gap* is calculated as the value-weighted or equal-weighted average price-to-book, price-to-sales, price-to-earnings, price-to-cashflow of high emission firms net of the value-weighted or equal-weighted average of low emission firms in the country/area. When a firm's $CO_2$ intensity is among the top 30% in the country-year-quarter, the firm is regarded as a high emission firm. When a firm's $CO_2$ intensity is among the bottom 30% in the country-year-quarter, the firm is regarded as a low emission firm. $CO_2$ intensity is defined as the sum of scope 1, 2 and 3 emissions over sales. Panel B shows the results of regressing *EMC Price Gap* on continuous year-quarter variable *Trend*. *EMC Price Gap* is calculated as the value-weighted or equal-weighted average price-to-book, price-to-sales, price-to-earnings, price-to-cashflow of firms with negative environmental news net of the value-weighted or equal-weighted average of firms without negative environmental news in the country/area. When a firm has been covered by negative environmental news in the past twelve months, the firm is regarded as an emission firm. When a firm has not been covered by negative environmental news in the past twelve months, the firm is regarded as a clean firm. Columns (1)–(4) report results for value-weighted *EMC Price Gap*. Columns (5)–(8) report results for equal-weighted *EMC Price Gap*. The control variables are the log GDP per capita, female ratio, corruption, government effectiveness, political stability, regulatory quality, rule of law, and accountability. The sample includes the 26 markets listed in Table I from 2007Q1 to 2020Q4. Standard errors are clustered by year-quarter and reported in parentheses. $^{*}p < .1$;$^{**}p < .05$;$^{***}p < .01$.

*Panel A: Price gaps between firms with high and low emission intensity*

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Value-weighted | | | | Equal-weighted | | | |
| | PB | PS | PE | PCF | PB | PS | PE | PCF |
| Trend | -0.015$^{***}$ | -0.052$^{***}$ | 0.116$^{***}$ | -0.033 | -0.012$^{***}$ | -0.043$^{***}$ | -0.044 | -0.098$^{***}$ |
| | (0.003) | (0.005) | (0.037) | (0.045) | (0.002) | (0.003) | (0.038) | (0.026) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1386 | 1386 | 1386 | 1386 | 1386 | 1386 | 1383 | 1386 |
| Adj. $R^2$ | 0.316 | 0.345 | 0.143 | 0.222 | 0.317 | 0.418 | 0.116 | 0.246 |

*Panel B: Price gaps between firms with and without negative environmental news*

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Value-weighted | | | | Equal-weighted | | | |
| | PB | PS | PE | PCF | PB | PS | PE | PCF |
| Trend | -0.027$^{***}$ | -0.069$^{***}$ | -0.077$^{*}$ | -0.043 | -0.027$^{***}$ | -0.050$^{***}$ | -0.059$^{*}$ | -0.176$^{***}$ |
| | (0.005) | (0.008) | (0.039) | (0.033) | (0.002) | (0.008) | (0.033) | (0.038) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 679 | 679 | 679 | 679 | 679 | 679 | 679 | 679 |
| Adj. $R^2$ | 0.398 | 0.361 | 0.163 | 0.365 | 0.533 | 0.566 | 0.166 | 0.417 |

**Table IA.III.** Yearly trends of firm-level prices

This table presents the trends of price ratios for emission vs. clean firms. The price ratios are *Log PB* in columns (1)–(3), *Log PS* in columns (4)–(6), *Log PE* in columns (7)–(9), and *Log PCF* in columns (10)–(12). *Emission* is an indicator of high-emission industries based on IPCC's categorization. Control variables consist of *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. The sample includes the 26 markets listed in Table I from 2007Q1 to 2020Q4. Standard errors are clustered by firm and by year-quarter, and reported in parentheses. $^{*}p < .1;^{**}p < .05;^{***}p < .01$.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Log PB | | Log PS | | Log PE | | Log PCF | |
| Year2008×Emission | -0.006* | 0.000 | 0.034*** | 0.038*** | -0.013*** | 0.005 | -0.012** | -0.010** |
| | (0.003) | (0.003) | (0.003) | (0.004) | (0.003) | (0.004) | (0.004) | (0.004) |
| Year2009×Emission | -0.006*** | -0.021*** | 0.053*** | 0.025*** | 0.014** | -0.012* | 0.032*** | -0.008 |
| | (0.002) | (0.002) | (0.002) | (0.001) | (0.006) | (0.006) | (0.005) | (0.005) |
| Year2010×Emission | 0.024*** | 0.001 | 0.076*** | 0.045*** | 0.057*** | 0.047*** | 0.046*** | 0.003 |
| | (0.003) | (0.003) | (0.004) | (0.003) | (0.009) | (0.009) | (0.007) | (0.007) |
| Year2011×Emission | 0.016*** | 0.003 | 0.058*** | 0.045*** | -0.007 | 0.020* | 0.061*** | 0.031*** |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.009) | (0.009) | (0.008) | (0.008) |
| Year2012×Emission | -0.035*** | -0.031*** | 0.010 | 0.013** | -0.067*** | -0.031*** | 0.029*** | 0.009 |
| | (0.006) | (0.006) | (0.006) | (0.006) | (0.010) | (0.010) | (0.009) | (0.009) |
| Year2013×Emission | -0.105*** | -0.083*** | -0.031*** | -0.018** | -0.089*** | -0.048*** | -0.066*** | -0.063*** |
| | (0.007) | (0.006) | (0.007) | (0.007) | (0.011) | (0.011) | (0.010) | (0.010) |
| Year2014×Emission | -0.114*** | -0.102*** | -0.041*** | -0.038*** | -0.047*** | -0.033** | -0.062*** | -0.074*** |
| | (0.007) | (0.007) | (0.008) | (0.007) | (0.012) | (0.011) | (0.010) | (0.010) |
| Year2015×Emission | -0.122*** | -0.150*** | -0.048*** | -0.091*** | -0.042*** | -0.091*** | -0.099*** | -0.153*** |
| | (0.008) | (0.008) | (0.009) | (0.008) | (0.012) | (0.012) | (0.011) | (0.011) |
| Year2016×Emission | -0.087*** | -0.118*** | -0.012 | -0.056*** | -0.003 | -0.050*** | -0.088*** | -0.138*** |
| | (0.008) | (0.008) | (0.009) | (0.009) | (0.013) | (0.012) | (0.011) | (0.011) |
| Year2017×Emission | -0.069*** | -0.076*** | 0.005 | -0.015 | 0.002 | -0.015 | -0.072*** | -0.100*** |
| | (0.008) | (0.008) | (0.009) | (0.009) | (0.015) | (0.013) | (0.011) | (0.011) |
| Year2018×Emission | -0.105*** | -0.086*** | -0.043*** | -0.030*** | -0.085*** | -0.062*** | -0.093*** | -0.098*** |
| | (0.008) | (0.008) | (0.010) | (0.009) | (0.016) | (0.013) | (0.012) | (0.011) |
| Year2019×Emission | -0.100*** | -0.082*** | -0.045*** | -0.028** | -0.102*** | -0.081*** | -0.093*** | -0.093*** |
| | (0.008) | (0.008) | (0.010) | (0.009) | (0.015) | (0.013) | (0.012) | (0.012) |
| Year2020×Emission | -0.095*** | -0.086*** | -0.044*** | -0.038*** | -0.066*** | -0.070*** | -0.093*** | -0.102*** |
| | (0.008) | (0.008) | (0.010) | (0.009) | (0.014) | (0.012) | (0.012) | (0.011) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | | Yes | | Yes | | Yes | |
| Country×Year FE | | Yes | | Yes | | Yes | | Yes |
| Obs. | 1192213 | 1192213 | 1158001 | 1158001 | 872701 | 872701 | 874169 | 874169 |
| Adj. $R^2$ | 0.665 | 0.684 | 0.759 | 0.768 | 0.553 | 0.565 | 0.521 | 0.533 |

**Table IA.IV.** Yearly trends of institutional and retail ownership

This table presents the trends of institutional and retail ownership for emission vs. clean firms. *Retail and Inst. Ownership (%)*, *Retail Ownership (%)*, *IO(%)* are ownership by retail and institutional investors, retail investors, and institutional investors. *IO(%)* is divided into ownership by domestic institutions *Domestic IO(%)* and foreign institutions *Foreign IO(%)*. *Emission* is an indicator of high-emission industries based on IPCC's categorization. Control variables consist of *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. The sample includes the 26 markets listed in Table I from 2007Q1 to 2020Q4. Standard errors are clustered by firm and by year-quarter, and reported in parentheses. $^{*}p < .1;^{**} p < .05;^{***} p < .01$.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Retail and Inst. Ownership(%) | Retail Ownership(%) | IO(%) | Domestic IO(%) | Foreign IO(%) |
| Year2008×Emission | 0.478*** | 0.699*** | -0.221** | -0.254*** | 0.033 |
| | (0.129) | (0.130) | (0.082) | (0.074) | (0.031) |
| Year2009×Emission | 0.396*** | 0.758*** | -0.363*** | -0.423*** | 0.061*** |
| | (0.054) | (0.056) | (0.024) | (0.026) | (0.009) |
| Year2010×Emission | 0.240** | 0.534*** | -0.294*** | -0.421*** | 0.127*** |
| | (0.085) | (0.091) | (0.052) | (0.056) | (0.020) |
| Year2011×Emission | 0.601*** | 1.026*** | -0.425*** | -0.508*** | 0.082** |
| | (0.156) | (0.165) | (0.097) | (0.096) | (0.035) |
| Year2012×Emission | 0.688*** | 1.401*** | -0.713*** | -0.676*** | -0.037 |
| | (0.198) | (0.209) | (0.122) | (0.116) | (0.045) |
| Year2013×Emission | 1.040*** | 1.865*** | -0.825*** | -0.708*** | -0.117** |
| | (0.223) | (0.239) | (0.128) | (0.124) | (0.051) |
| Year2014×Emission | 1.000*** | 1.741*** | -0.741*** | -0.691*** | -0.050 |
| | (0.238) | (0.258) | (0.136) | (0.133) | (0.057) |
| Year2015×Emission | 0.840*** | 1.597*** | -0.757*** | -0.664*** | -0.093 |
| | (0.263) | (0.276) | (0.164) | (0.151) | (0.064) |
| Year2016×Emission | 0.770** | 1.525*** | -0.755*** | -0.710*** | -0.045 |
| | (0.283) | (0.294) | (0.177) | (0.160) | (0.069) |
| Year2017×Emission | 0.121 | 0.669** | -0.548** | -0.536*** | -0.011 |
| | (0.295) | (0.306) | (0.184) | (0.166) | (0.073) |
| Year2018×Emission | -0.457 | 0.231 | -0.689*** | -0.662*** | -0.027 |
| | (0.309) | (0.322) | (0.189) | (0.170) | (0.076) |
| Year2019×Emission | -0.784** | -0.083 | -0.700*** | -0.627*** | -0.073 |
| | (0.312) | (0.327) | (0.192) | (0.172) | (0.077) |
| Year2020×Emission | -1.207*** | -0.409 | -0.797*** | -0.647*** | -0.150* |
| | (0.300) | (0.316) | (0.191) | (0.171) | (0.074) |
| Controls | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes |
| Country×Year FE | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1229379 | 1229379 | 1229379 | 1229379 | 1229379 |
| Adj. $R^2$ | 0.618 | 0.689 | 0.850 | 0.849 | 0.742 |

**Table IA.V.** $CO_2$ emission and price gaps: Public firms

This table presents the results of regressing $CO_2$ emission by public firms on price gaps. Panel A reports results for $CO_2$ emission intensity. Panel B reports total $CO_2$ emission. *EMC Price Gap* is the average price gap over the past year in the country/area. Columns (1) to (3), (4) to (6), and (7) to (9) define *EMC Price Gap* as the value-weighted average price-to-sales, price-to-earnings, and price-to-cashflows of emission firms net of the value-weighted average of clean firms in the country/area, respectively. *Log Scope1*, *Log Scope2*, and *Log Scope3* are the log of one plus total scope one, scope two, scope three $CO_2$ emissions. *S1int*, *S2int*, and *S3int* are total scope 1, scope 2 and scope 3 $CO_2$ emissions over total sales. *Emission* is an indicator of high-emission industries based on IPCC's categorization. *IO(%)* is the ownership by institutional investors. *ESG Disclosure* equals one if the country-year has the ESG mandatory disclosure requirement. Control variables consist of firm-level price ratios, *Log Total Assets*, *Book Leverage*, *Cash/Total Assets*, and *ROE*. The sample includes the 26 markets listed in Table I from 2007 to 2020. Standard errors are clustered by firm, and reported in parentheses. $^{*}p < .1;^{**}p < .05;^{***}p < .01$.

Panel A: $CO_2$ emission intensity

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | EMC PS Gap | | | EMC PE Gap | | | EMC PCF Gap | | |
| | S1int | S2int | S3int | S1int | S2int | S3int | S1int | S2int | S3int |
| Emission×EMC Price Gap | 5.802** | 0.620 | 2.260*** | 1.196*** | -0.039 | 0.374*** | 0.870* | -0.151 | 0.281*** |
| | (2.564) | (0.540) | (0.433) | (0.337) | (0.033) | (0.054) | (0.472) | (0.250) | (0.104) |
| IO(%) | 0.034 | 0.013 | 0.025* | 0.064 | 0.018 | 0.022 | 0.034 | 0.016 | 0.024 |
| | (0.082) | (0.014) | (0.014) | (0.094) | (0.016) | (0.015) | (0.085) | (0.015) | (0.015) |
| Emission×IO(%) | 0.256 | -0.013 | -0.082** | 0.336 | -0.029 | -0.071** | 0.335 | -0.029 | -0.070** |
| | (0.289) | (0.026) | (0.032) | (0.328) | (0.029) | (0.032) | (0.319) | (0.028) | (0.032) |
| Emission×ESG Disclosure | -102.663*** | 0.420 | -3.089 | -109.934*** | 0.372 | -4.873* | -105.591*** | -0.809 | -4.538 |
| | (28.916) | (2.823) | (3.268) | (31.067) | (2.948) | (2.885) | (31.084) | (3.001) | (3.323) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country×Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 75121 | 75121 | 75119 | 63606 | 63606 | 63604 | 64660 | 64660 | 64659 |
| Adj. $R^2$ | 0.852 | 0.840 | 0.957 | 0.855 | 0.846 | 0.961 | 0.859 | 0.854 | 0.960 |

Panel B: Total $CO_2$ emission

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | EMC PS Gap | | | EMC PE Gap | | | EMC PCF Gap | | |
| | Log Scope1 | Log Scope2 | Log Scope3 | Log Scope1 | Log Scope2 | Log Scope3 | Log Scope1 | Log Scope2 | Log Scope3 |
| Emission×EMC Price Gap | 0.030*** | 0.032*** | 0.037*** | 0.003*** | 0.000 | 0.003*** | 0.004** | 0.005*** | 0.006*** |
| | (0.007) | (0.006) | (0.004) | (0.001) | (0.001) | (0.001) | (0.002) | (0.002) | (0.001) |
| IO(%) | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 | -0.000 |
| | (0.001) | (0.000) | (0.000) | (0.001) | (0.000) | (0.000) | (0.001) | (0.000) | (0.000) |
| Emission×IO(%) | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 |
| | (0.001) | (0.001) | (0.000) | (0.001) | (0.001) | (0.000) | (0.001) | (0.001) | (0.000) |
| Emission×ESG Disclosure | 0.084 | -0.019 | -0.095*** | 0.044 | -0.044 | -0.139*** | 0.105 | 0.004 | -0.090*** |
| | (0.071) | (0.071) | (0.036) | (0.069) | (0.070) | (0.031) | (0.069) | (0.074) | (0.028) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country×Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 75121 | 75121 | 75119 | 63606 | 63606 | 63604 | 64660 | 64660 | 64659 |
| Adj. $R^2$ | 0.945 | 0.926 | 0.970 | 0.947 | 0.927 | 0.975 | 0.946 | 0.925 | 0.976 |

**Table IA.VI.** Green patents and price gaps: Public vs. private firms

This table reports the regression results of green patents on price gaps. *EMC Price Gap* is the average price-to-book gap over the past twelve quarters. Columns (1)–(2) show the results for public firms that have matched private firms. Columns (3)–(5) show the results for public firms that have matched private firms and their matched private firms. *Green Ratio (%)* is the proportion of green patents that the firm files in the year-quarter. *Emission* is an indicator of high-emission industries based on IPCC's categorization. *ESG Disclosure* equals one if the country-year-quarter has the ESG mandatory disclosure requirement. *Public* equals one if the firm is listed. The control variable is *Log Total Assets*. The sample includes the 26 markets listed in Table I from 2011Q1 to 2018Q4. Standard errors are clustered by firm and by year-quarter, and reported in parentheses. $^{*}p < .1;^{**} p < .05;^{***} p < .01$.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Dep. Var.: Green Ratio (%) | Public with match | | Public vs. Private | | |
| Emission | 0.818*** | | 2.591*** | | |
| | (0.238) | | (0.727) | | |
| EMC Price Gap | 0.001 | | 0.021 | | |
| | (0.100) | | (0.158) | | |
| Emission×EMC Price Gap | -0.504*** | -0.551** | 0.764* | 0.206 | 0.212 |
| | (0.172) | (0.238) | (0.422) | (0.271) | (0.271) |
| Emission×ESG Disclosure | | | | | 0.782 |
| | | | | | (0.821) |
| Public | | | 0.182 | 0.190 | 0.192 |
| | | | (0.224) | (0.241) | (0.240) |
| Emission×Public | | | -1.876** | -0.534 | -0.535 |
| | | | (0.778) | (0.409) | (0.409) |
| EMC Price Gap×Public | | | 0.119 | 0.208 | 0.208 |
| | | | (0.164) | (0.164) | (0.164) |
| Emission×EMC Price Gap×Public | | | -1.266*** | -0.644* | -0.644* |
| | | | (0.456) | (0.329) | (0.329) |
| Controls | Yes | Yes | Yes | Yes | Yes |
| Year-Quarter FE | Yes | | Yes | | |
| Firm FE | | Yes | | Yes | Yes |
| Country×Year-Quarter FE | | Yes | | Yes | Yes |
| Obs | 86453 | 85171 | 218104 | 215476 | 215476 |
| Adj. $R^2$ | 0.005 | 0.315 | 0.007 | 0.443 | 0.443 |