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Executive Summary

To what extent has climate risk been priced into equity markets? Is there a “brown” discount and a “green” premium? Has this shifted over time? How can we model such risks as the world moves toward net-zero targets?

In this paper, we studied the financial impact of climate transition risk in global equity markets. We identified economic transmission channels within a standard discounted cash flow model showing how regulatory policies and green technology influence financial markets. For example, in developed markets outside the U.S., more carbon-efficient companies experienced stronger stock-price performance over a seven-year study period. In contrast, in emerging markets, less carbon-efficient companies fared better across the study period, although more carbon-efficient companies performed better in recent years, which was also true for the U.S.

We also found companies’ green revenue share was clearly associated with higher earnings growth and higher relatively better stock performance within a given sector. This finding provided support for the green technology-related transmission channel.

Next, we compared companies’ climate transition risk profiles to their valuation levels. Carbon-intensive companies experienced greater declining valuations in terms of price-to-book ratios than did their less-carbon-intensive sector peers — suggesting that markets have discounted the book value of carbon-intensive companies during the study period. In contrast, companies with significant green revenue saw their price-to-earnings ratios increase relative to their sector peers.

Companies’ earnings growth and stock performance were directly related to their greenhouse gas (GHG) emissions. Using five MSCI Low Carbon Transition (LCT) categories, we found that the riskiest category (stranded assets) had the weakest performance, and the solutions category had the strongest during the study period. While most performance differences were explained by the industry factor, there was a significant stock-specific return that showed a strong correlation to companies’ climate transition risk profile.

When we included LCT Scores in a standard risk model, we found a positive return attached to the climate transition risk profile, which has accelerated over the past two years. The performance was particularly strong in the two categories at the tails: stranded assets and solutions. In contrast, in the largest category which is composed of companies with “neutral” exposure, the observed stock-price and earnings impact was small.
Introduction

Under the 2015 Paris Agreement, global political leaders adopted a goal of limiting the increase in global average temperatures to well below 2°C above pre-industrial levels. To achieve this objective, countries defined a national emission reduction path — Nationally Determined Contributions, or NDCs — which ultimately will be mapped onto different sectors and onto individual companies. Countries’ ambitions for reducing GHG emissions, as reflected in their NDCs, vary significantly, as shown in Exhibit 1.

Exhibit 1: Normalized Relative Target Level of NDCs per Region

Ambition of NDC pledges vs BAU

Data reflecting the pledged GHG goals found in the Nationally Determined Contributions (NDCs) submitted to the 2015 COP21 conference in Paris, sourced from NDC Registry. To make countries’ NDCs comparable, MSCI ESG Research rebased countries’ NDCs in terms of reduction of countries’ GHG emissions as a percentage of countries’ respective 2030 business-as-usual (BAU) emissions, which reflect the emissions trajectory of the country without any climate policy. Note that new NDCs are expected to be submitted by member countries during 2021. Source: MSCI ESG Research.

The European Union has the most ambitious target. We estimate that its NDC effectively represents a 50% to 60% reduction on 2030 “business as usual” (BAU) emissions. In contrast, the U.S.’s pledge corresponds to an estimated 30% to 40% reduction. In emerging markets, we observe even lower ambitions: For example,
China’s NDC translates to an estimated 10% to 20% emissions reduction as compared with 2030 BAU emissions.

Many corporations will have to adjust their operations and/or their products and services to meet their countries’ NDCs and future climate policies. Some companies, such as BP, Ford Motor and CEMEX, have already set ambitious net-zero goals. For global investors, these policy changes may pose risks to their holdings. How can investors best evaluate these risks?

Investors also might ask whether climate risks are already fully priced in financial markets. To the extent that companies’ business models are visibly exposed to transition risks (such as a shift to a low-carbon economy) or physical risks (such as extreme weather conditions), have markets completely reflected those risks?

The scope of this paper is to understand to what extent climate risk has been priced into equity markets and whether climate change can be modeled using a typical risk model structure, exemplified in this formula:

\[
\text{Financial climate risk impact} = \text{climate risk exposure} \times \text{climate risk driver}
\]

We address three key areas in this paper:

1. **Economic drivers of climate change**: What are the economic drivers of climate change? How can we explain climate change’s impact on financial markets?

2. **Climate risk exposure**: How can we measure or proxy companies’ climate risk exposure in financial models? How can we define meaningful climate risk categories within a broad global equity universe, such as MSCI ACWI IMI?

3. **Financial climate risk impact**:
   
   a. Has climate risk affected companies’ valuation levels? Did carbon-intensive companies receive a price discount, and “greener” companies a premium? Has this changed over time?

   b. How has climate risk affected stock-price performance or earnings-growth performance? Did climate change risk qualify as an equity risk factor?

In the next section, we summarize the data and methodologies used for our empirical analysis. We then develop the fundamental economic transmission channels to explain the potential impact of climate change on equity prices, including empirical evidence for climate policies and green technology as financial risk drivers. We also study the impact of climate-transition risk on valuation levels and trends. We follow with a discussion of how to measure and categorize companies’ climate-risk exposures and how to integrate climate-transition risks into risk models.
# Data and Methodology

## DESCRIPTORS

We use the following descriptors to characterize companies’ climate change profiles as a basis for our analysis\(^1\) (descriptors come from MSCI climate data and metrics):

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon intensity</td>
<td>The amount of Scope 1 and 2 GHG (direct emissions and electricity use) in tons of CO(_2)-equivalent (tCO(_2)e) per USD 1 million of sales.</td>
</tr>
<tr>
<td>Scope 3 carbon intensity</td>
<td>The amount of Scope 3 GHG emissions in tCO(_2)e per USD 1 million sales, based on MSCI’s Scope 3 Estimation Model, generated by a company’s supply chain. This covers all 15 categories of upstream and downstream Scope 3 emissions, as defined by the Greenhouse Gas Protocol. Details on the methodology can be found in Hadjikyriakou et al. (2020).</td>
</tr>
<tr>
<td>Reserve intensity</td>
<td>Potential GHG emissions in million tCO(_2)e embedded in companies’ coal, oil and gas reserves per USD 1 million market capitalization.</td>
</tr>
<tr>
<td>Green revenue share</td>
<td>The share (in percent) of a company’s revenue derived from alternative energy, energy efficiency and green building.</td>
</tr>
<tr>
<td>Carbon beta</td>
<td>A measure of the sensitivity of a company’s stock price to (European) CO(_2) price movements. Technically, it is the beta regression coefficient of the residual return from the MSCI GEMLT risk model on the price returns of the allowances traded under the European Union Carbon Emission Trading Scheme (EU ETS).</td>
</tr>
<tr>
<td>Low-carbon patents score</td>
<td>The cumulative score of all granted low-carbon patents held by a company, based on the MSCI ESG Research methodology. Low-carbon, or “green” patents, are distinguished from other patents based on their patent classification as per the Cooperative Patent Classification. Scores are attributed to patents based on patent citations, the amount and size of countries in which protection is granted and the patent sector classification.</td>
</tr>
<tr>
<td>Low Carbon Transition Score (LCT Score)</td>
<td>A measure of a company’s climate transition risk arrived at by aggregating Scope 1, 2 and 3 emissions, avoided emissions and the quality of companies’ climate management into a score between 0 (highest risk) and 10 (lowest risk/highest opportunity).</td>
</tr>
<tr>
<td>Low Carbon Transition Category (LCT Category)</td>
<td>A category assigned to a company that highlights the predominant transition risks and opportunities the company is most likely to face. The LCT Category is based on the LCT Score. There are five LCT Categories: stranded assets, product transition, operation transition, neutral and solutions. Details can be found in Badani et al. (2019).</td>
</tr>
</tbody>
</table>

\(^1\) The descriptors are all data fields proprietary to MSCI ESG Research LLC.
Missing data values were omitted in the analysis universe, except for the factor return regression where missing LCT Scores were replaced by 0.\(^2\)

**EMISSIONS-RELATED SECTOR EXPOSURES**

Which sectors have the greatest exposure to carbon risk? We assessed median levels of these descriptors across Global Industry Classification Standard (GICS\(^\circledast\)) sectors.\(^3\) The indicators can be grouped into carbon footprint (or “brown”) indicators, climate change readiness (or “green”) indicators and price-sensitivity (or “risk”) indicators. We ordered sector-specific results by decreasing emission intensity, i.e., from the highest (utilities) to the lowest (financials).

We had different historical data available for the different descriptors.\(^4\) To provide statistically significant results, we used the longest available history for each descriptor in our simulations, which means the time periods shown in our study vary depending on which descriptors were used.

Exhibit 2 illustrates that the utilities, materials and energy sectors provided the highest levels of emissions and fossil fuel reserves. (Some companies in other sectors also had fossil fuel reserves in related group subsidiaries.)

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\(^2\) See Exhibit 21.

\(^3\) GICS is the global industry classification standard jointly developed by MSCI and Standard & Poor’s.

\(^4\) In Exhibit A2, we summarized the available data history and cross-sectional coverage for the different climate indicators.
Companies not only are exposed to climate change risks due to their Scope 1 and Scope 2 emissions, they also face exposure from their supply chain and the emissions caused by their products and services. These emissions are measured by companies’ Scope 3 GHG emissions. The Greenhouse Gas Protocol comprises 15 categories of Scope 3 emissions, including upstream activities (for instance, purchased goods and services) and downstream activities (for instance, use of sold products).

For the constituents within the MSCI ACWI Investable Markets Index (IMI), the largest source of Scope 3 GHG emissions comes from Category 11, the so-called use of sold products. In the energy sector, Scope 3 emissions represented 89.3% of total GHG emissions as of October 2020 — which is not surprising as the sector’s products center almost entirely on fossil fuels burned for power generation, transportation or manufacturing. Another industry with significant Scope 3 emissions is the automobiles GICS industry within the consumer discretionary sector, where the use of the cars produced causes the majority of GHG emissions.

Interestingly, the three most carbon-intensive sectors are also among the sectors holding most of the patents related to green technology — alongside the IT and

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5 MSCI ACWI IMI is a global equity index covering more than 8,000 securities across large-, mid- and small-cap segments in 49 developed and emerging markets.
Industrials sectors (Exhibit 3) — suggesting that these companies are seeking to change their business models.

**Exhibit 3: Distribution of “Green” Indicators per GICS sector**

![Graph showing distribution of green revenue share and low carbon patents score per GICS sector](Image)

*Data from Nov. 30, 2015 (green revenue share) or Dec 31, 2014 (low carbon patents score) to Jan. 31, 2021. For each sector, we show 25th, 50th and 75th percentiles of monthly sector averages over the sample period.*

Carbon beta values — a market-implied proxy for how dependent companies are on the price of carbon emissions — were small across all sectors (see Exhibit 4), but not unreasonably so considering that carbon beta shows the impact on residual returns, after stripping out the impact on returns of common factors including industry and countries. The energy sector had the lowest (most negative) median value for carbon beta, indicating that this sector had residual returns the most negatively impacted by an increase in (European) carbon prices.
Exhibit 4: Distribution of Climate Transition Risk Indicators per GICS Sector

Data from July 31, 2012 (carbon beta) or Oct. 31, 2013 (LCT Score) to Jan. 31, 2021. For each sector, we show 25th, 50th and 75th percentiles of monthly sector averages over the sample period.

DATA TRANSFORMATION

We normalized the data to address the skew in the distribution for some of the variables so that a higher numerical value always corresponds to a more “climate-friendly” company profile (see Exhibit A1 in the Appendix). All carbon emission-related variables were transformed onto a logarithmic scale and we flipped the sign, effectively making them a measure for carbon efficiency. The low-carbon patent score and companies’ green revenue share were also transferred to a log scale.

We also examined correlations: Exhibit A3 showed relatively low levels of correlation among the three types of climate indicators (brown, green and risk indicators) as well as between climate indicators and GEMLT factors (Exhibit A4). This finding suggests that these different climate indicators have been relatively independent descriptors in our performance and risk analysis.
Drivers and Transmission Channels of Transition Risk

In *Risk, Uncertainty, and Profit*, University of Chicago economist Frank H. Knight explained 100 years ago that *risk* is present when the set of potential future events is known and occurs with measurable probability; *uncertainty* is present when the complete set or likelihood of future events is indefinite or incalculable (Knight, 1921).

Efficient markets can be expected to price risk efficiently, but the same may not hold for uncertainty due to unknown probabilities of future events or incomplete knowledge about the set of future states of the economic system.

While climate change is largely referred to as a “risk” in the public debate, in reality it is an “uncertainty,” as scientific estimates for the probability distribution of future climate temperature scenarios vary widely (Exhibit 5). Thus, the likelihood and the relative economic impact are practically unknown.

Exhibit 5: Scientific Estimates of the Likelihood of Future Degree Scenarios


But the ability to price risks becomes more certain as risks become more defined. For example, the 2015 Paris Agreement and subsequent commitments by different...
countries to cut emissions have provided markets with very tangible and therefore “priceable” pieces of information.

In this section, we explore the economic transmission channels that explain how policies and technology drive the process of turning uncertainty into priceable risk information and how these channels can be verified empirically. We focus on two drivers — government policies and green technology — as they are very prominent in the public and academic debate on climate change. However, in practice there may be many other drivers, such as a shift in consumer preferences; however, these are beyond the scope of our analysis.

CLIMATE POLICY AS A CLIMATE TRANSITION RISK DRIVER

Policies and regulations are the political key drivers for countries implementing NDCs. To gain a theoretical understanding of the economic transmission channels from climate-related policies to priceable financial market impact, we looked at Integrated Assessment Models (IAMs), which outline pathways for the transition of the global economy to a low-carbon economy. For instance, in June 2020 the Network for Greening the Financial System (NGFS) published a set of climate scenarios using three IAMs (GCAM, MESSAGEix-GLOBIOM and REMIND-MAgPIE). These models combine economic aspects, land use, energy and climate systems in a consistent quantitative framework to model cost-efficient decarbonization pathways. These scenarios describe the policy-induced reduction of emissions as a key driver to climate change, implying increasing operational and cost impacts on companies, which we summarize in Exhibit 6:

Exhibit 6: Hypothetical Transmission Channel of Climate Policies

We now look for empirical evidence supporting this hypothetical transmission channel.

Given the regional differences in the ambitiousness of countries’ NDCs, we examine the relationship between regions and climate-related stock price performance. We

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7 The models are described in some detail the NGFS technical documentation (NGFS 2020). In addition, further model documentation is available at https://www.iamcdocumentation.eu/index.php/IAMC_wiki.

8 See Exhibit 1.
are especially interested in differences between developed markets (DM) and emerging markets (EM) and, within DM, between the U.S. and the rest of DM. Therefore, we used three regional subsets of the MSCI ACWI IMI universe: a U.S. index (MSCI USA IMI), a developed-market non-U.S. index (MSCI World ex USA IMI) and an emerging-market index (MSCI EM IMI). For each of these benchmarks, we divided the universe sector by sector into Scope 1 and 2 carbon-efficiency quintiles on a monthly basis and compared the performance difference between the top and the bottom quintiles, as well as the difference in earnings growth (Exhibit 7).

Carbon-efficient companies in the MSCI World ex USA Index experienced superior stock performance and earnings growth. In contrast, in emerging markets, the most carbon-efficient companies showed slight underperformance compared with less carbon-efficient companies, and similar levels of earnings growth over time. In the U.S., results were mixed: More carbon-efficient companies showed lower earnings growth but slightly better performance, albeit clearly below the MSCI World ex USA Index returns. From the time of Donald Trump’s election as the U.S. president in November 2016, more carbon-efficient companies in the U.S. underperformed their less-carbon-efficient peers for about two years; since mid-2018, though, their stocks have rebounded and subsequently outperformed.

Exhibit 7: Top vs. Bottom Carbon-Efficiency Quintiles

Differences in EPS growth are shown in the left plot; stock returns are charted in the right plot. Data from Oct. 31, 2014, to Jan. 31, 2021. EPS growth is taken from the GEMLT model, and uses five-year smoothing.

In developed markets (ex U.S.), the outperformance of more carbon-efficient companies was driven by the majority of companies in the sample. This is apparent in the cumulative specific return contribution of the lowest and highest quintiles in carbon efficiency shown in Exhibit 8. In the U.S., the top carbon-efficient quintile of
companies outperformed. In emerging markets, the opposite was true, i.e., the majority of top quintile companies showed a negative specific return.

Exhibit 8: Cumulative Specific Return vs. Cumulative Active Weight

Data from Oct. 31, 2014, to Jan. 31, 2021 Note: The jump in the U.S. (around the 140% mark) is entirely due to Gamestop’s performance in January 2021.

Carbon efficiency has been more financially relevant in developed markets (ex U.S.) than in the U.S. and EM. This observation is consistent with developed markets’ stronger political commitment to a low-carbon economy, especially the European Union’s 2018 pledge to become carbon-neutral by 2050. This echoes our map in Exhibit 1 that shows that Europe had the most ambitious climate change agenda; EM, the least.

It is worth noting the relationship between firms’ environmental performance and financial performance since the advent of environmental policies in Western countries in the 1970s (Spicer, 1978). The “Porter Hypothesis” (Porter and van der Linde, 1995) suggests that strict environmental regulation can result in innovation by polluting firms. Subsequently, that hypothesis has been reformulated into a weak form (environmental regulation may lead to innovation but not necessarily to better financial performance) and a strong form (environmental regulations may lead to better financial performance; Ambec et al., 2011). The Porter Hypothesis has given rise to a stream of empirical research with generally inconclusive results (Dechezlepretre and Kruse, 2018). As a result, more recent research has tended to

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9 The large stock-specific return in the U.S. was due to GameStop.
focus more on the question of under what circumstances the Porter Hypothesis may hold (Albertini, 2013).

The lack of conclusive results may be explained by the regional difference in performance that we observed in Exhibits 7 and 8. Our findings lend support to the Porter Hypothesis for developed markets, but not for EM, where the level of technical readiness as well as the political framework are not yet transforming the local economy to the same extent toward decarbonization.

**Carbon Emission Costs’ Impact on Earnings and Stock Returns**

To validate the hypothetical climate transmission channel, we assessed whether emission-related costs showed an impact on earnings and stock performance (the last step in the transmission channel). Given that the EU Emissions Trading System (ETS) constitutes the largest carbon trading system worldwide, we used the prices of the EU ETS allowances (EUA).

We examined the most carbon-intense sectors in Europe — utilities, energy and materials — and ordered companies in each sector according to their sensitivity to the EUA price (measured by the carbon beta) into top quintiles (most positive price sensitivity) and bottom quintiles (most negative price sensitivity).

Exhibit 9 shows the top versus bottom performance in term of earnings growth and stock performance compared with the European carbon price for the three carbon-intense sectors. During the study period, we saw that companies with more positive or less negative carbon price-sensitivity showed a positive earnings growth trajectory, closely aligned with the price increase of carbon. We also found those companies’ stocks have outperformed since 2016, albeit with some time lag when compared with the earnings-growth trajectory.

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10 In a separate study, we examined whether climate-related events led to an immediate change in stock prices. However, the results were mixed as some events, e.g., the 2015 Paris Agreement, might have been anticipated by markets. Thus, we are focusing solely on the last step of our transmission model in this section.
These findings support the last step in the transmission channel: In exposed sectors, the European carbon price was a cost factor that was associated with companies’ earnings and, ultimately, their stock price. There is a broad selection of literature that found similar results. For instance, Tian et al. (2016) found a negative association between European carbon prices and returns of stocks of carbon-intensive utilities and a positive association with the returns of stocks of “cleaner” utilities.
**GREEN TECHNOLOGY AS CLIMATE TRANSITION RISK DRIVER**

The development and rollout of green technology is another key component of the transition to a low-carbon economy and a core part of the inner workings of IAMs. Although IAMs produce scenarios at a macroeconomic level, we are interested in the implications for the performance for firms, i.e., at the microeconomic level. We evaluate green technology’s role in a hypothetical transmission channel (Exhibit 10).

**Exhibit 10: Hypothetical Transmission Channel of Green Technology**

In our analysis, we used two indicators as a proxy for companies’ involvement in green technology: low-carbon patent scores and companies’ share of green revenue.11 Low-carbon patents (or “green patents”) can serve as a proxy for companies’ ownership of green technologies, which may in turn lead to actual green earnings growth; as such, they are useful to test the first step in the transmission channel. Green revenue share indicates to what extent companies have monetized green technology and allows us to test the second half of the transmission channel.

Green patents were mainly concentrated in materials, IT, energy and industrials, while green revenue was mainly present in real estate, IT, financials, utilities and industrials (Exhibit 11).12

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11 Green patents and green revenue have been used in previous research, for instance in Dechezlepretre et al. (2017), Kruse et al. (2020a) and Kruse et al. (2020b).

12 Upon further investigation, the green revenue in the financial sector was driven by revenue in the equity real estate investment trusts (REITs) industry, which was shifted to the real estate GICS sector in August 2016. After 2016, the current level of green revenue shares in financials is actually very low (average of 0.05% as of February 2021).
Exhibit 11: Green Revenue Share vs. Green Patent Score per GICS Sector

Median values by sector for green revenue share start Nov. 30, 2015. Low-carbon patents score starts Dec. 31, 2014. The sample ends on Jan. 31, 2021. We found a median low-carbon patent score above zero in only five sectors; those are the basis of our subsequent analysis.

Therefore, we focus our analysis on those sectors that had either significant positive low-carbon patent scores and/or a high share of green revenue: utilities, materials, energy, real estate, industrials and IT.

To test the left side of the transmission channel in Exhibit 10, we investigated how much the growth rate of green revenue was driven by innovation in green technologies. We compared earnings growth and stock performance of companies with high low-carbon patent scores versus those with lower low-carbon patent scores. Exhibit 12 compares earnings growth and stock performance in the upper half versus lower half of low-carbon patent scores in each sector.
Exhibit 12: Top Half vs. Bottom Half in Terms of Low-Carbon-Patent Scores

Data from Jan. 31, 2015, to Jan. 31, 2021. EPS growth is taken from the GEMLT model and uses five-year smoothing.

We found that in the most emission-intense sectors — utilities, materials and energy — higher patent scores coincided with higher earnings growth. However, in the industrials and IT sectors, this was not the case. We did not consider real estate in Exhibit 12 as the median low-carbon patent score in that sector is zero. In addition, intra-sectoral differences in patent scores were not clearly aligned with differences in stock performance.

There are several possible explanations for the lack of a clear performance direction in low-carbon patent scores. First, not all green technology investments are patented, and not every green patent is equally significant in terms of creating new revenues for a company. In addition, it is not always necessary to own the patent to a green technology to use the technology and generate green revenue. For example, utilities may generate substantial green revenue from alternative energy by using alternative energy equipment, without owning the patent for it. The same is true for green building technologies used in the real estate sector. Finally, there can be significant time lags between innovation (i.e., patents), earnings growth and stock performance, as shown in the transmission channel. Successful technologies may trigger earnings growth after a period of years, which may then be reflected in stock performance. Therefore, a six-year time period (the study period used in Exhibit 12) may be too
short to find significant financial results linked to patent scores, as the patented technology often take years to develop and then years more to become profit. The typical time horizon needed to monetize green patents may also vary by sector.

To test the hypothesis of whether green revenue may be financially relevant once it materializes, we sorted companies in each GICS sector according to their share of green revenue and compared the upper quintiles against the lowest quintiles in terms of both earnings growth and stock performance (Exhibit 12).

We observed that, within sectors with significant green revenue, companies with a high share of green revenue showed significantly higher earnings growth than their sector peers with a low green revenue share, except for the real estate sector, where differences were negligible. In addition, this earnings growth advantage was also associated with higher stock performance in all sectors (except real estate, which showed no earnings growth difference).

**Exhibit 13: Top Quintile in Green-Revenue Share vs. Bottom Quintile**

Data from Nov. 30, 2015, to Jan. 31, 2021. EPS growth is taken from the GEMLT model and uses five-year smoothing

Overall, our findings suggest that innovation in green technology (measured by the patent score) showed only a relatively weak association with higher earnings growth and therefore the empirical evidence for the left side of the transmission channel in
Exhibit 10 is muted. However, where green revenue had materialized, it was clearly accompanied by stronger relative stock performance, which provides empirical support during our study period for the right-hand side of the transmission channel in Exhibit 10.

Our findings are in line with Kruse et al. (2020a) who found that utilities with higher proportions of “green” revenue tended to have higher profit margins, which led to higher relative valuation levels.

Next, we probe deeper into the financial impact on stock-valuation levels and stock-price performance.

**VALUATION EFFECTS OF CLIMATE TRANSITION**

Now that we have found support for the economic transmission channels, we take a closer look at whether equity markets repriced stock of companies based on climate considerations. We address two questions:

1. Whether firms’ climate transition risk profiles had an impact on their valuation levels during the study period.
2. Whether this impact has changed over time — i.e., have we observed any empirical evidence for a shift in investors’ preferences or risk aversion.

To address the first question, we tested whether lower GHG emissions or higher green revenue shares were associated with higher price-to-book (P/B) and price-to-earnings (P/E) ratios in a standard regression model. To address the second question, we assessed the trends in the regression coefficients over time.

First, we regressed companies’ P/B and P/E ratios versus their carbon efficiency and green revenue share as explanatory variables.

We ran a monthly regression within MSCI ACWI IMI using regions, sectors and style factors (size, momentum, growth, earnings variability, profitability, residual volatility) and oil-price sensitivity as control variables. The 12-month moving averages of the cross-sectional regression coefficients for P/B and P/E ratios are shown in Exhibits 14 and Exhibit 15, respectively.

In the P/B analysis (Exhibit 14), we found that more-carbon-efficient companies tended to have higher valuation levels and showed an increasing trend in their

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13 Style factors were selected based on their correlation with P/B and P/E variables. We also tested other control sets, which always included regions and sectors, only the list of style factors varied. The smaller control set contained the size factor, and the larger control set contained all style factors except the ones directly correlated with the dependent variable, i.e., B/P and P/E.
relative valuation levels. On the other hand, for companies’ green revenue shares the regression coefficient was volatile without as clear a trend as we found for carbon efficiency.

**Exhibit 14: P/B Regression Coefficients**

Data from Oct. 31, 2014, to Jan. 31, 2021. The chart shows the rolling 12-month average of the cross-sectional regression coefficient of companies’ P/B ratios to carbon efficiency and green revenue share. All regressors are z-scored and winsorized at +/-3.

For the P/E analysis (Exhibit 15), the picture is almost the opposite: The carbon efficiency regression coefficients for Scope 1 and 2 emissions were volatile without a clear trend and flipping signs several times during the study period. On the other hand, the green revenue share coefficient showed a clear positive trend, going from a negative to a positive valuation effect during the study period.
Exhibit 15: P/E Regression Coefficients

Data from Oct. 31, 2014, to Jan. 31, 2021. The chart shows the rolling 12-month average of cross-sectional regression coefficient of companies’ P/E ratios to carbon efficiency and green revenue share. All regressors are z-scored and winsorized at +/-3. For t-statistics data, see the Appendix.

These findings are in line with previous academic studies. For instance, from 2011 to 2015 (prior to the Paris Agreement), Berkman et al. (2019) found that a measure of climate risk was negatively associated with Tobin’s Q measures for U.S. non-financial firms and positively associated with the cost of capital.14 Similarly, Atanasova and Schwartz (2019) investigated North American oil firms over the period from 1999 to 2018 and found that an increase in their reserves was negatively associated with those firms’ Tobin’s Q measures, especially in countries with more stringent climate policies — leading the authors to conclude that markets penalized the valuation of companies with reserves growth.

The difference between the P/B and P/E analysis is worth highlighting: Price-to-book is a more backward-looking analysis, because book value represents past earnings and past buildup of companies’ balance sheets. The fact that our price-to-book regression showed a more significant trend for carbon efficiency could mean that during the study period, investors became increasingly skeptical as to whether the

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14 The ratio of a firm’s enterprise value to the book value of its assets.
book value of companies heavily reliant on carbon-intensive activities is sustainable in the long run. In other words, investors may have become more risk-averse toward potentially stranded assets on companies’ balance sheet and started to “discount” companies’ book values in their pricing of equities.

To probe deeper, we regressed companies’ P/B ratio versus companies’ reserve efficiency for the energy and utilities sectors — the sectors that hold most of the fossil fuel reserves. The regression coefficient showed a clear upward trend over time for both sectors (Exhibit 16), providing further evidence for financial markets building a discount into P/B valuation levels.

Exhibit 16: P/B Regression on Reserve Efficiency: Utilities and Energy Coefficients

In contrast, the P/E analysis is a more forward-looking view of how markets price companies’ future business potential. Here, green revenue share was the strongest trend indicator, meaning investors were increasingly willing to pay higher valuation multiples for companies with more green revenue, which could be in line with expectations for larger future earnings.

We also looked at the regression coefficients at a sector level. Utilities and materials statistically had the most significant regression coefficients in their Scope 1 and 2 carbon-efficiency regression. The IT sector showed a significant regression
coefficient for green revenue share, which reflects that the IT sector has one of the highest green revenue exposures (Exhibit 3), mainly from selling equipment for alternative energy and products for energy efficiency.

VALIDATING VALUATION TRENDS

To assess the significance of the observed trends in P/B and P/E, we ran a separate regression to test whether the trendline fitted on the time-series of monthly t-statistics was significantly upward or downward sloping during our study period. We calculated these trend coefficients both at the MSCI ACWI IMI level and the sector level.

The analysis in Exhibit 17 confirms our previous findings: More emission-efficient companies in terms of Scopes 1, 2 and 3 experienced a clear positive trend in P/B ratios, and a very significant upward trend in P/E ratios for companies’ green revenue share.

Exhibit 17: T-statistics of Linear Trends in Regression Coefficients

Exhibit 17: T-statistics of Linear Trends in Regression Coefficients


Examining at the sector level, we found the strongest trend in the carbon-efficiency coefficient in the P/B ratio regressions for utilities, materials and energy, whereas in other sectors the trend was weaker or even slightly negative. For P/E ratio, financials — in addition to materials, energy and utilities sectors — showed the most significant trends.
Finally, we viewed sector-level trends of companies’ reserve efficiency in the utilities and energy sectors, which hold most of the fossil fuel reserves among MSCI ACWI constituents (Exhibit 18). In the energy and utilities sector, stocks of companies with large fossil fuel reserves experienced an increasing discount in terms of P/B ratios.

**Exhibit 18: T-statistics of Linear Trends in Regression Coefficients**

All in all, we found consistent support for a clear shift in investors’ way of pricing climate change. On one hand, carbon-intensive sectors saw an increasing discount priced on the book value of their equity, implying that investors became increasingly risk-averse. On the other hand, companies with green revenue exposure became increasing expensive in terms of their earnings multiples.
Modeling and Measuring Financial Transition Risk

We will now explore how to integrate climate transition risks into financial risk models.

MEASURING AND CATEGORIZING TRANSITION RISK EXPOSURE

We can proxy and categorize companies’ transition risk profile by combining risk exposure (climate policy risk) and opportunity exposure (green technology), using standardized indicators such as companies’ GHG emissions. We used companies’ Low Carbon Transition (LCT) Scores as a comprehensive measure for transition risk. The score aggregates companies’ risks due to direct emissions (Scope 1, Scope 2), risks due to their upstream supply chain (Scope 3 upstream emissions) and risks inherent in their products and services (Scope 3 downstream emissions). The LCT Scores take into account companies’ green opportunity exposure by measuring avoided emissions from green technology in Scope 3 emissions and companies’ climate transition risk management.

Next, we assess to what extent companies’ aggregate climate-transition exposures (proxied by their LCT Scores) may explain stock performance. Therefore, we integrated the LCT Score into a standard equity risk model (MSCI GEMLT) to measure performance effects and to control for other systematic factors.

In addition, the LCT Score is used to categorize companies’ transition risk exposure into five LCT Categories within MSCI ACWI IMI (Exhibit 19). We observe that the largest group on both measures was the neutral category, while the two most extreme categories — stranded assets and solutions — were the smallest.

Exhibit 19: Breakdown of MSCI ACWI IMI into Climate-Transition Categories

<table>
<thead>
<tr>
<th>LCT CATEGORY</th>
<th>DESCRIPTION</th>
<th># STOCKS</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset stranding</td>
<td>Potential to experience &quot;stranding&quot; of physical or natural assets due to regulatory, market and technological forces arising from &quot;low-carbon&quot; transition.</td>
<td>75</td>
<td>1%</td>
</tr>
<tr>
<td>Product transition</td>
<td>Reduced demand for carbon-intensive products and services. Winners and losers are defined by the ability to shift product portfolio to low-carbon products.</td>
<td>483</td>
<td>10%</td>
</tr>
<tr>
<td>Operational transition</td>
<td>Increased operational and capital cost due to carbon taxes and investment in carbon emissions mitigation measures leading to lower profitability of companies.</td>
<td>1013</td>
<td>9%</td>
</tr>
<tr>
<td>Neutral</td>
<td>Limited exposure to &quot;low-carbon&quot; transition risk. Companies could face physical risk or indirect exposure to transition risk via lending, investment operations.</td>
<td>5539</td>
<td>74%</td>
</tr>
<tr>
<td>Solutions</td>
<td>Potential to benefit through the growth of low-carbon products and services.</td>
<td>304</td>
<td>3%</td>
</tr>
</tbody>
</table>

Data from Oct. 30, 2013, to Jan. 31, 2021
To assess whether these emission-based categories adequately described companies’ climate transition risk, we ran a stock performance and earnings growth analysis of the LCT Categories on the MSCI ACWI IMI universe using hypothetical equal-weighted portfolios with monthly re-balancing (Exhibit 20).

Exhibit 20: Cumulative EPS Growth (left) and Stock Performance (right)

Data from Oct. 31, 2013, to Jan. 31, 2021. EPS growth is taken from the GEMLT model and uses five-year smoothing.

The two highest-risk categories (stranded assets and product transition) underperformed significantly, while solution companies outperformed in terms of both stock performance and earnings growth. In fact, the relative stock performance of the different categories was in the exact same order as for the LCT Categories.

INTEGRATING TRANSITION RISK EXPOSURE INTO RISK MODELS

As a third step, we conducted a performance attribution to see to what extent these performance results were due to common factors. To be precise, we measured the active performance of each LCT Category (“long leg”) against the MSCI ACWI IMI (“short leg”). Both legs were equally weighted, with monthly re-balancing.

The results in Exhibit 21 show again the monotonic relationship between LCT Categories and performance, from stranded assets to solutions companies. For the higher-risk LCT Categories (stranded assets and product transition), most of the underperformance was explained by industry factor, which is in line with our earlier findings that direct and indirect emissions are very concentrated in a few sectors and consequently in a few industries. In addition, the stranded assets category showed a significant performance contribution from equity style factors, especially the momentum factor.
In addition, there has been a significant stock-specific performance contribution — especially in the solutions LCT Category. The specific return contribution is important as it indicates the return not explained by common equity factors; to what extent can these specific returns be explained by differences in companies’ LCT Scores? To address this question, we sorted companies in each LCT Category (the long leg) in increasing order of LCT Score and plotted the cumulative specific return over the cumulative portfolio weight for each category (Exhibit 22).
Specific returns were most significant in the solutions category: We found a convex curve, which means that solutions companies with higher LCT Scores had higher stock-specific returns than solutions companies with lower LCT Scores.

The stranded assets category also showed a strong degree of convexity in the cumulative return curve, with lower LCT Scores showing negative stock-specific returns and higher LCT Scores positive specific returns.\(^{15}\)

We also observed a certain degree of convexity in the cumulative specific return curves for the product transition and operational transition categories in the lower half of the curve, while they were closer to a linear relationship at the upper end of the LCT Score range in those categories. On the other hand, stocks in the neutral LCT Category showed relatively little aggregate stock-specific return and no convexity. Overall, this shows that the stock-specific returns that can be attributed to the LCT

\(^{15}\) This finding explains why the aggregate stock-specific return for the stranded assets category in Exhibit 8 was quite small: Positive and negative stock specific returns were offsetting each other.
Scores were very concentrated in the most climate transition risk-exposed categories, in line with our intuition.

Could companies’ climate transition risk profiles (as measured by their LCT Scores) serve as an additional equity risk driver? To assess this question, we included LCT Scores as a hypothetical driver in the factor return estimation of the MSCI GEMLT model to obtain the return associated with the LCT Score, i.e. the return after taking into consideration all existing factors in the GEMLT model.

The resulting cumulative returns associated with the LCT Score are shown in Exhibit 23 and are quite intuitive: Overall, LCT Scores showed a positive return that was relatively small in the first half of the study period, but accelerated substantially during the last two years of the study period. The growing strength of LCT Scores may provide additional support for the policy- and technology-related transmission channels in Exhibits 6 and 10, as climate-related policies and technology have increased since the Paris Agreement was adopted in late 2015.

**Exhibit 23: Cumulative Returns of the LCT Score**


The improved value of LCT Scores provides support that during the study period climate-transition risk had been a price factor, alongside traditional equity style factors. However, price impact was mainly concentrated in the most exposed LCT Categories, while there was little stock price impact in the largest neutral category.
This finding is in line with Goergen et al. (2020) who found that a “carbon risk factor” existed between 2010 and 2017, as measured by an indicator for companies’ transition risk that used GHG emissions and ESG variables.

Our findings contrast, however, with those of Bolton and Kacperczyk (2020), who found that carbon-intense companies outperformed their “greener” peers from 2005 to 2018 using a global equity universe. The authors termed this a “carbon premium.”

Our study is more focused on the time after the Paris Agreement. Our analysis suggests that the increasing price discount of carbon-intense companies after the Paris Agreement went hand in hand with a relative decline in earnings and stock performance for those companies.

SECTORAL ANALYSIS

In Exhibit 20, we observed a significant performance contribution from the industry factor, which may raise the question of how different GICS sectors were affected by climate transition risk. Exhibit 24 shows that utilities, materials and energy were the most-exposed sectors in terms of higher-risk LCT Categories. In contrast, practically all stocks in the communication services, financials and health-care sectors were in the neutral LCT Category, showing relatively little impact from climate risk on stock performance. Also, most consumer staples and IT stocks were in the neutral category.
Were sector-relative differences in LCT Scores within most-exposed sectors associated with differences in performance? We divided on a monthly basis the utilities, energy and material sectors into quintiles of LCT Scores and looked at the difference in average stock returns and EPS growth between the lowest quintile (high transition risk) to the highest quintile (lowest transition risk) in Exhibit 25.

Exhibit 25: Top vs. Bottom LCT Score Quintiles

Data from Oct. 31, 2013, to June 2020. EPS growth is taken from the GEMLT model and uses five-year smoothing.
In all three sectors, we saw very clear stock-price outperformance related to high versus low LCT Scores. In the utilities and materials sectors, higher LCT scores were also associated with relatively higher earnings growth.

HOW CLIMATE TRANSITION RISKS MATERIALIZED

We can draw four key conclusions from these results:

1. Although emissions data is typically reported with a significant time lag, our analysis showed that companies’ total emissions profile as measured by the LCT Score and LCT Category provided a meaningful way to proxy and categorize their transition-risk exposure, as shown by differences in earnings growth and stock performance. This may be because companies’ involvement in carbon-intensive activities and/or climate solutions has not changed over short periods of time; emissions and green revenue reported some months ago have provided a good proxy for companies’ transition-risk exposure. For financial risk models, this means that companies’ emissions profiles represent the climate transition-risk exposure, rather than the climate-risk driver. The results also support the Bank of International Settlement’s proposal that providing a firm-level green rating based on a company’s total emissions profile could provide a useful signal to investors (Ehlers et al., 2020).

2. Transition risk was not uniformly distributed across MSCI ACWI IMI: The financial impact was mainly concentrated in the two smallest and most extreme categories, i.e., asset stranding and solutions, while the financial impact was small in the neutral LCT Category (accounting for 74% of the benchmark by market capitalization).

3. For asset stranding and solutions, there was a strongly non-linear relationship between companies’ LCT Scores and stock-specific returns, which suggests that companies’ emissions profiles provided a relevant stock-price factor alongside common style factors.

4. The financial effects of climate transition risk appeared continuously over time and have accelerated significantly since 2019, which mirrors the findings in Giese et al. (2020), which found climate risk to be a long-term “erosion risk.” This finding can be explained by the economic transmission channels, which show how policies and technology potentially drove the process of transforming climate uncertainty into “priceable” pieces of climate risk information over time.
From a financial risk management perspective, investors may want to consider that the observed financial erosion process may continue as climate policy, green technology and financial markets evolve. Financial climate stress scenarios, as proposed by the Task Force for Climate-related Financial Disclosure (TCFD) may help simulate or extrapolate a continuation of the observed financial erosion path into the future.\textsuperscript{16}

Future research may focus on whether the observed acceleration in stock-price impact continues, and to what extent the financial impact may spread more broadly to the neutral LCT Category. Researchers may also explore whether there are additional economic transmission channels that can potentially drive financial effects, such as climate-related shifts in consumer behavior.\textsuperscript{17}

\textsuperscript{16}TCFD recommendations for disclosing climate-related risks, June 2017.

\textsuperscript{17}Existing literature also looked at other financial aspects of climate transition risk, such as systematic risks in equity markets (De Angelis, 2020), tail risks (Ilhan et al., 2020) and the influence of climate-related disclosure on financial performance (Matsumura et al. 2014).
Conclusion

We identified two economic transmission channels that help explain how climate policies and green technology may transform climate uncertainty into tangible risk parameters priceable by financial markets. Looking for empirical evidence, we found regional differences in NDCs to be associated with regional differences in financial performance: In developed markets (ex U.S.), we saw the biggest relative performance advantage during our seven-year study period for more-carbon-efficient companies versus their less-carbon-efficient sector peers in terms of stock-price and earnings growth. In contrast, emerging markets had less-carbon-efficient companies that outperformed their “greener” sector peers during the entire study period (though improving in the past two years), which was in line with less-ambitious NDCs in emerging markets. The U.S. sat in the middle of these extremes.

We also found that climate transition has shifted during the study period: Carbon-intensive companies have seen a relative downward trend in their price-to-book valuation, which means markets started to effectively “discount” book values that can be linked to carbon-intensive activities. In contrast, companies with high exposure to green revenue have seen their price-to-earnings ratio rise, which means investors were willing to pay an increasing premium to gain exposure to technology that has the potential to replace the existing carbon-intensive infrastructure.

Companies across the five LCT Categories (stranded assets, product transition, operational transition, neutral and solutions) showed very different stock-performance and earnings-growth patterns. While most of the performance difference was explained by the industry factor, we found a significant stock-specific performance contribution associated with differences in companies’ GHG emissions. This performance contribution was particularly strong in the most extreme risk categories: stranded assets (highest risk) and solutions (lowest risk/highest opportunity). We were also able attribute inter-sectoral performance differences among the most-carbon-efficient and the least-carbon-efficient quintiles to differences in green technology and green revenue. We also found that the LCT Score provided a positive return when used in GEMLT, which increased in the past two years, providing additional evidence that climate transition risk should be considered as an additional risk factor.

In addition, we found clear evidence that climate transition risk unfolds in the shape of erosion risk, rather than event risk. This finding provides empirical support for conducting climate stress scenarios as one way to extrapolate the observed financial erosion path into the future.
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### Historical Coverage of Climate Indicators

#### Exhibit A1: Overview of Company-Specific Climate Indicators and Covered Universe

<table>
<thead>
<tr>
<th>Data</th>
<th>Raw data</th>
<th>Unit of raw data</th>
<th>Transformation</th>
<th>Start date</th>
<th>ACWI IMI coverage, approx.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon efficiency</td>
<td>Carbon intensity</td>
<td>tCO₂e / USD million</td>
<td>-log(Carbon intensity)</td>
<td>Oct 2014</td>
<td>8400</td>
</tr>
<tr>
<td>Scope 3 carbon efficiency</td>
<td>Scope 3 carbon intensity</td>
<td>tCO₂e / USD million</td>
<td>-log(Scope 3 carbon intensity)</td>
<td>Oct 2014</td>
<td>6700</td>
</tr>
<tr>
<td>Reserve efficiency</td>
<td>Reserve intensity</td>
<td>MtCO₂e / USD million</td>
<td>-log(reserve intensity)</td>
<td>Jan 2010</td>
<td>270</td>
</tr>
<tr>
<td>Green revenue share</td>
<td>Green revenue share raw</td>
<td>%</td>
<td>log(Green revenue share %)</td>
<td>Nov 2015</td>
<td>1600</td>
</tr>
<tr>
<td>Low Carbon Patents Score</td>
<td>Low Carbon Patents Score raw</td>
<td>1</td>
<td>log(Low Carbon Patents Score raw)</td>
<td>Jan 2015</td>
<td>1600</td>
</tr>
<tr>
<td>Carbon beta</td>
<td>Carbon beta</td>
<td>1</td>
<td>None</td>
<td>July 2012</td>
<td>8600</td>
</tr>
<tr>
<td>Low Carbon Transition Score</td>
<td>Low Carbon Transition Score</td>
<td>1</td>
<td>None</td>
<td>Oct 2013</td>
<td>7600</td>
</tr>
<tr>
<td>Low Carbon Transition Category</td>
<td>Low Carbon Transition Category</td>
<td>None</td>
<td>None</td>
<td>Oct 2013</td>
<td>7600</td>
</tr>
</tbody>
</table>
Exhibit A3 shows the correlation matrix across seven climate indicators: The average level of correlation was low. We found some positive correlation between direct carbon efficiency (Scope 1 and 2) and indirect carbon efficiency (Scope 3), whereas potential emissions were negatively correlated to both types of carbon efficiency. This indicates that as far as emissions are concerned, more efficient operations and products tend to be associated with lower carbon reserves. By contrast, their “green indicators” — patent score and green revenue share — were practically uncorrelated.
Exhibit A3: Cross-Sectional Correlation Matrix of Climate Indicators

Data from Oct. 31, 2014, to Jan. 31, 2021

Exhibit A4 shows correlations between companies’ climate indicators and GEMLT style factors, which were quite low on average. Among the most notable correlations were the following: Larger companies tended to have higher low-carbon patent scores, less green revenue and lower carbon reserves. Earnings quality was negatively correlated with carbon efficiency.

Exhibit A4: Correlation Matrix of Climate Indicators with GEMLT Style Factors

Data from Oct. 31, 2014, to June 31, 2021
<table>
<thead>
<tr>
<th>PUBLICATION</th>
<th>METHODS</th>
<th>CLIMATE-RELEVANT MEASURES USED</th>
<th>SAMPLE DESCRIPTION</th>
<th>TIME PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aklin (2018)</td>
<td>Event study</td>
<td>Separation of firms by sector</td>
<td>42 publicly listed international clean energy firms and 200 publicly listed international listed fossil fuel producers</td>
<td>November 2016</td>
</tr>
<tr>
<td>Atanasova and Schwartz (2019)</td>
<td>Regression analysis</td>
<td>Oil reserves and growth in oil reserves</td>
<td>600 oil firms in North America</td>
<td>1999 to 2018</td>
</tr>
<tr>
<td>Bolton and Kacperczyk (2020)</td>
<td>Regression analysis</td>
<td>GHG emissions (Scopes 1, 2 and 3; Trucost)</td>
<td>3,917 publicly listed firms from the United States, across sectors</td>
<td>2005 to 2017</td>
</tr>
<tr>
<td>Clarkson et al (2015)</td>
<td>Regression analysis</td>
<td>GHG emissions (Scopes unclear; as reported by facilities under the EU ETS, plus CDP data)</td>
<td>221 listed European firms with facilities participating in the EU ETS, across sectors</td>
<td>2006 to 2009</td>
</tr>
<tr>
<td>Goergen et al (2020)</td>
<td>Regression analysis</td>
<td>Own &quot;Brown-Green-Score&quot; based on GHG emissions (Scopes 1 and 2; CDP), other ESG Data (MSCI, Sustainalytics and Thomson Reuters)</td>
<td>1,657 listed international firms, across sectors (ex-financial)</td>
<td>2010 to 2017</td>
</tr>
<tr>
<td>Study</td>
<td>Methodology</td>
<td>Key Variables</td>
<td>Sample Size/Scope</td>
<td>Time Period</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>----------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Ilhan et al (2020)</td>
<td>Regression analysis</td>
<td>GHG emissions (Scope 1; CDP)</td>
<td>Approximately 500 firms from the USA, across sectors</td>
<td>2009 to 2016</td>
</tr>
<tr>
<td>Kruse et al (2020b)</td>
<td>Event study</td>
<td>GHG emissions (Scopes 1 and 2; Trucost), green revenues (FTSE Russell)</td>
<td>5,000+ publicly listed firms from the USA, across sectors</td>
<td>December 2015</td>
</tr>
<tr>
<td>Matsumura et al (2014)</td>
<td>Regression analysis</td>
<td>GHG emissions (Scopes unclear; CDP), environmental performance data (MSCI-KLD)</td>
<td>Approximately 500 firms from the USA, across sectors</td>
<td>2006 to 2008</td>
</tr>
<tr>
<td>Monasterolo and De Angelis (2020)</td>
<td>Regression analysis</td>
<td>Low carbon versus carbon intensive indexes</td>
<td>EU, US and global stock indexes, across sectors</td>
<td>Unclear</td>
</tr>
<tr>
<td>Ramelli et al (2018)</td>
<td>Event study</td>
<td>GHG emissions (Scopes 1 and 2; CDP and Vigeo Eiris), &quot;climate responsibility&quot; score based on ESG data (MSCI-KLD, Vigeo Eiris)</td>
<td>766 listed US firms, across sectors</td>
<td>Windows around November and December 2016</td>
</tr>
<tr>
<td>Tian et al (2016)</td>
<td>Regression analysis</td>
<td>Electricity utilities with more than 50% of generation from fossil fuels</td>
<td>12 European electricity utilities</td>
<td>2005 to 2012</td>
</tr>
</tbody>
</table>
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