Carbon Premium: Is It There?

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Abstract

The carbon premium refers to the excess return associated with the carbon-brown firms and is the focus of several recent influential studies. After accounting for the data release lag and with value weighting, less carbon-intensive firms deliver higher returns in the U.S., while there is no excess return associated with total carbon emissions and emission growth. Internationally, the carbon return is zero on average and is lower in countries with strong in-sample green shocks during the transition, such as sustainable flows and climate concerns. After controlling for the in-sample shocks, the carbon return is higher in countries more exposed to climate change.

Keywords: carbon emissions, climate change, predictability, stock returns

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The science broadly agrees that the reduction in carbon emissions is required to fight climate change and avoid catastrophic consequences. As the potential regulations and social atmosphere turn against the brown firms, the brown firms would need higher required rate of return to compensate investors for the increased carbon-transition risk. This is called the carbon premium. Bolton and Kacperczyk (2021, 2022) (BK, 2021, 2022) conclude that the statistically significant carbon premium exists both in the U.S. and globally for all three categories of emissions. However, the carbon premium only exists for the total level of emissions and the year-by-year change in emissions, but not the emission intensity. Overall, they conclude that investors are already demanding compensation for their exposure to carbon emission risk. Related, Görgen et al. (2020) find a brown premium for the level of carbon risk, and Hsu, Li and Tsou (2022) document a brown premium using the toxic emission intensity. However, Aswani, Raghunandan and Rajgopal (2022) find that the carbon premium disappears once they control for firm characteristics, standard error clustering, and firm disclosure, and Lindsey, Pruitt and Schiller (2021) find mixed results. Moreover, In, Park and Monk (2017) and Pedersen, Fitzgibbons and Pomorski (2021) find a green premium with respect to the carbon intensity and Pástor, Stambaugh and Taylor (2022) document a green premium using the MSCI greenness score.

Using the same data as BK, this paper examines the economic and statistical evidence of the carbon premium. From both the U.S. and international analysis, I find that the evidence of in-sample carbon premium is weak. Instead, there is a strong value-weighted green premium in the U.S. equity market empirically, but not broadly internationally. Further analysis shows that the variations across countries are more driven by in-sample sustainable flows and climate-concern shifts instead of data mining. Overall, It is unreliable to conclude that investors have already repriced the carbon risk and extrapolate average in-sample carbon returns to form future expectations.

This paper conducts the analysis in four steps. First, I start with measures of the carbon-transition risk. Consider a simple model in which firms have different carbon efficiency (or, intensity) and face stochastic carbon tax shocks. The carbon emissions grow with the output as in the data. As the carbon regulatory risk increases, the firms with higher carbon intensity have lower asset and employment growth and earn higher expected returns than the green ones. In sum, the carbon intensity helps capture the firm-level carbon-transition risk when firms face regulatory risks, such as carbon tax, cap-and-trade, or even harsher regulations as long as the firm is allowed to trade the carbon quota.

Second, I revisit the U.S. evidence and conduct value-weighted portfolio sorting using lagged carbon intensities, e.g. carbon emissions scaled by sales, carbon emissions, and emission growth. I account for the release lag in the carbon data by using the actual release date provided by the data vendor. The median of the release lag is 10 months, and the 75th percentile is 24 months, longer than that of most accounting variable. Overall, the brown firms earn lower returns than the green firms in sample. The value-weighted return spread per month are -0.52% and -0.54% for the scope 1 and 2 carbon intensities. After adjusting for the FF6 factor exposures, the alphas of the long-short excess returns are as large as -0.48% and -0.57% per month, respectively. However, there are no excess returns associated with the total emissions or emission growth, suggesting that these variables do not capture carbon risk.

Next, I follow BK's approach and run a pooled panel regression. Consistent with BK (2021), I find that there is a strong positive contemporaneous carbon premium associated with total emissions and emission growth, but no significant relation associated with carbon intensity. However, when the stock return is related to the lagged carbon footprint in investors' information sets, there is no significant carbon return for any measure. Note that the ordinary-least-squares regressions tend to overweight the smaller stocks, because they are more susceptible to outliers, and volatile returns, which most likely belong to smaller stocks. I thus account for these concerns by running weighted-least-square regressions instead and find that the carbon intensities are significantly associated with lower future stock returns, while the carbon emissions and emission growth are not, consistent with the portfolio-based evidence.

Finally, I turn to the intentional sample. Using value-weighted portfolio sorting with lagged carbon intensities, I find that carbon premium does not exist on average internationally. Instead, the returns have huge dispersion across countries. Adjusting for the factor exposures further strengthens the dispersion in carbon returns. One possible interpretation is that investors do not really care about the carbon risk and the green premium in the U.S. is merely a result of data mining. Alternatively, investors' shift in attention and preference differs across countries, which in turn drives cross-country mean carbon return variations. In equilibrium, the brown stocks should earn higher expected returns to compensate investors for taking on heightened carbon risk. In the short run, the green premium can arise due to in-sample climate concern shocks or price pressure arising from investor flows (Pástor, Stambaugh and Taylor, 2022).

I measure the shift in investor preference by the country-level sustainable flows and surveyed climate concern. The developed countries have experienced stronger climate-aware shifts in both investor and consumer preference, and the carbon returns are lower in more developed countries in sample. The results suggest that the transition to the new equilibrium with full carbon awareness is aggressively underway. It is too soon to conclude on the expected carbon premium based on the carbon returns in recent years. Furthermore, after controlling for the in-sample shocks, I find that countries with higher physical exposure to climate change and tighter climate policies earn higher carbon returns in sample.

This paper adds to the literature that studies the carbon pricing as discussed earlier. This rapidly growing literature has been making a number of different choices in the analysis, such as the data lag for the carbon data, estimation technology, and weighting scheme. The release lag in the carbon data is often not provided by the data vendor. This paper provides a first assessment of the release lag and finds that the lag is longer than typical accounting variables. This makes a significant difference in the inference especially for total emissions and emission growth, which contain accounting information about the firm. After accounting for the data lag and value-weighting, I find no evidence of carbon premium in the U.S. or internationally. Related, broadly to examine whether investors care about the carbon risk, Krueger, Sautner and Starks (2020) document that the average respondent believes that the climate risk is not fully priced in market valuations in a survey of institutional investors, and Giglio, Kelly and Stroebel (2021) further provide an extensive review of the carbon pricing in various markets.

Second, this paper contributes to the country-level literature on climate finance. The paper closest to this one is BK (2022). This paper differs in two ways. First, I show that after accounting for the data lag and value-weighting, there is no carbon or green premium on average internationally in contrast to BK (2022). Second, BK (2022) interprets the carbon return variations across countries as the risk premium variations and this paper highlights the role of in-sample shocks, such as sustainable flows and climate concerns, complementing the U.S.-based discussion in Pástor, Stambaugh and Taylor (2022). Related, Dyck et al. (2019) and Gibson et al. (2022) study the responsible institutional investing around the world. Notably, neither of these studies addresses the pricing implications.

The remainder of the paper proceeds as follows. Section 1 provides a simple model to characterize the carbon-transition risk. Section 2 discusses the data. Section 3 studies the U.S. evidence and benchmarks against the literature, and section 4 studies the international evidence. Section 5 analyzes what drives the cross-country variations in carbon returns. Finally, section 6 concludes.

1 A Theoretical Framework

There are two dates, t and $t+1$. The economy is populated with a representative household and heterogeneous firms, indexed by $i = 1, 2, ...N$. Firms produce a single good to be consumed or invested. Firm i starts with the productive capital K_{it}, operates in both dates, and exists at the end of date $t+1$ with a liquidation value of zero. The capital fully depreciates each period. Firms differ in capital K_{it}, capital profitability X_{it}, and carbon intensity ϕ_i. The output or sales is denoted by Y and the carbon emission is denoted by GHG,

$$\begin{aligned} Y_{it} &= X_{it}K_{it} + \chi_{it}L_{it}, \\ GHG_{it} &= \phi_i Y_{it}. \end{aligned} \tag{1}$$

Firm i's profitability at date $t+1$, X_{t+1}, is stochastic, and is subject to aggregate shocks affecting all firms simultaneously, and firm-specific shocks affecting only firm i. Let I_{it} be the investment for date t, and then $K_{it} = I_{it}$. Both investment and labor entail quadratic adjustment costs, $\frac{a}{2}\left(\frac{I_{it}}{K_{it}}\right)^2 K_{it}$ and $\frac{\alpha}{2}L_{it}^2$, where $a > 0$ and $\alpha > 0$.

The government levies a carbon tax on the firm-level carbon emissions each period. Each firm is allowed a carbon cap of $\overline{GHG}$, which will not be taxed. For firms with higher carbon emissions, they pay the carbon tax on the additional emissions $GHG_{it} - \overline{GHG}$. If firms have lower carbon emissions than $\overline{GHG}$, the firms can trade the carbon quota to other firms and get reimbursed for the carbon tax. The profit π_{it} equals

$$\begin{aligned} \pi_{it} &= Y_{it} - \tau_t(GHG_{it} - \overline{GHG}) \\ &= (1 - \phi_i \tau_t) Y_{it} + \tau_t \overline{GHG}, \end{aligned} \tag{2}$$

The stochastic tax rate τ_t is mean zero and normally distributed.

If the free cash flow

$$D_{it} = (X_{it}K_{it} + \chi_{it}L_{it})(1 - \phi_i\tau_t) - I - \frac{a}{2}\left(\frac{I_{it}}{K_{it}}\right)^2 K_{it} + \tau_t\overline{GHG} - \frac{\alpha}{2}I_{it}^2 \tag{3}$$

is positive, the firm distributes it back to the household. A negative D_{it} means external equity raised by the firm from the household. At date $t+1$, firm i uses capital, K_{it+1}, to obtain operating profits, which are then fully distributed as dividends,

$$D_{it+1} = (X_{it+1}K_{it+1} + \chi_{it+1}L_{it+1})(1 - \phi_i\tau_{it+1}) + \tau_{t+1}\overline{GHG}. \tag{4}$$

With only two periods, the firm does not investment in date $t+1$, $I_{it+1} = 0$, and the ex-dividend equity value P_{it+1} equals zero.

The household's stochastic discount factor, M_{t+1}, is

$$\log M_{it+1} = \log\beta - \lambda_x \Delta \log X_{t+1} + \lambda_\tau \tau_{t+1} - \frac{\alpha}{2}L_{it+1}^2, \tag{5}$$

where $\lambda_x > 0$, $\lambda_\tau > 0$. That is, positive aggregate profitability shocks indicate good times for the representative household. Positive carbon tax shocks are negative shocks to the household, because firms tend to reduce the investment in expectation of higher carbon taxes as I show below.

Firm i chooses I_{it} and L_{it} to maximize the cum-dividend equity value at the beginning of date t

$$\begin{aligned}P_{it} + D_{it} =& \max_{I_{it}} (X_{it}K_{it} + \chi_{it}L_{it})(1 - \phi_i\tau_t) + \tau_t\overline{GHG} - I_{it} - \frac{a}{2}\left(\frac{I_{it}}{K_{it}}\right)^2 K_{it} - \frac{\alpha}{2}L_{it}^2 \\ &+ E_t\left[M_{t+1}\left((X_{it+1}K_{it+1} + \chi_{it+1}L_{it+1})(1 - \phi_i\tau_{t+1}) - \frac{\alpha}{2}L_{it+1}^2 + \tau_{t+1}\overline{GHG}\right)\right].\end{aligned} \tag{6}$$

The first principle of investment for firm i says that,

$$1 + a\frac{I_{it}}{K_{it}} = E_t\left[M_{t+1}X_{it+1}(1 - \phi_i\tau_{t+1})\right]. \tag{7}$$

Because $E_tM_{t+1}\tau_{t+1} > 0$, more carbon-insensitive firms (higher ϕ_i), start downsizing and have lower investment growth rate under the stochastic carbon-tax rate. This is a capital-adjustment channel through which that the firms transition to the new net-zero economy.

The optimality condition for labor reads

$$L_{it} = \frac{\chi_{it}}{\alpha}(1 - \phi_i\tau_t). \tag{8}$$

The total employment is increasing the marginal labor productivity χ_{it}, but decreasing in the carbon tax rate τ_t.

The expected stock return in date $t+1$ can then be calculated as

$$\begin{aligned}r_{i,t+1}^S &= \frac{P_{it+1} + D_{it+1}}{P_{it}} \\ &= \frac{X_{it+1}(1 - \phi_i\tau_{t+1}) + \frac{1}{I_{it}}\left(\frac{\chi_{it+1}^2}{2\alpha}(1 - \phi_i\tau_{t+1})^2 + \tau_{t+1}\overline{GHG}\right)}{E_t\left[\left(1 + a\frac{I_{it}}{K_{it}}\right) + \frac{1}{I_{it}}\left(\frac{\chi_{it+1}^2}{2\alpha}(1 - \phi_i\tau_{t+1})^2M_{t+1} + \overline{GHG}\tau_{t+1}M_{t+1}\right)\right]}\end{aligned} \tag{9}$$

First, more carbon-intensive firms have higher expected return through the possibility of stranded assets. This can be seen by assuming that the firm operates with only capital and no labor ($\chi = 0$) and the carbon policy is linear in carbon emissions with no caps $\overline{GHG} = 0$. The equation then becomes $E_t r^S_{i,t+1} = \frac{E_t X_{it+1}}{E_t\left[1+a\frac{I_{it}}{K_{it}}\right]}$. Because more carbon-intensive firms have lower investment growth as shown in equation (7), they have higher expected expected returns.

Second, more carbon-intensive firms also require higher expected returns during increased risk exposure through the labor channel. This can be seen by assuming that the firm operates with only labor and no capita ($X = 0$). The equation then becomes $E_t r^S_{i,t+1} \approx \frac{E_t \chi^2_{it+1}}{E_t\left[\chi^2_{it+1} M_{t+1}(1-2\phi_i \tau_{t+1})+2\alpha \overline{GHG} \tau_{t+1} M_{t+1}\right]}$. As such, the more carbon-intensive firms (higher ϕ_i) have lower valuations through the exposure to the carbon risk $E_t\left[\chi^2_{it+1} M_{t+1}(1-2\phi_i \tau_{t+1})\right]$ and in turn higher expected returns. Firms with more carbon-intensive output (high ϕ_i) are more exposed and require higher expected returns to compensate investors for bearing the additional carbon-transition risk.

1.1 Discussions

The model shows that the carbon intensity can help capture the exposure to the carbon policy shock. In the model, the policy shock τ_t is a carbon tax. The policy can also be interpreted as a cap-and-trade policy, in which $\overline{GHG}$ is the carbon emission cap or quota for each company and τ is the effective rate at which the firms can trade their carbon quota. Firms with emissions lower than the carbon quota can sell their carbon quota to other companies at the unit cost of ϕ_t, and firms with higher emissions can buy carbon offsets and carbon quota to reduce their net carbon emissions.

One can imagine much harsher policies in which each firm is only allowed a fixed quota of carbon emissions and no trade on the emission cap is allowed. However, companies will be forced to circumvent the rules by spinning off certain plants and subsidiaries. In other words, the economy will be less concentrated with smaller average firm size, but with no effective material carbon reduction. In sum, the carbon intensity is a better measure of the carbon-transition risk than total carbon emissions, because it reflects the material carbon risk that the firm faces when adjusting business models and technologies.

Alternatively, the policy shock can also be interpreted a shift in consumer sentiment. The consumers can shun the brown products or are only willing to pay a discounted price for the brown products. Under this interpretation, the carbon cap $\overline{GHG}$ is more likely to be zero. Instead, consumers simply gauge the carbon intensity of the firms and products. The more carbon-intensive firms are likely to experience declining future profitability and stranded assets, lower valuations, and higher expected returns.

2 Data

The data on firm's climate performance source from S&P Trucost, which provides annual information on firm-level carbon emissions in tons of carbon dioxide (CO2) equivalent (tCO2e). The firm-level stock market and accounting information source from CRSP and Compustat for the U.S. and Compustat Global for the international sample. I restrict the sample to common stocks and focus only on the primary security listed on the primary exchange. The Trucost data is matched to the stock-level information by cusip, ISIN and SEDOL. Finally, I augment the data by country-level information extracted from the World Bank, Morningstar, World Risk Poll, and Climate Change Performance Index (formerly known as Germanwatch).

Figure 1 illustrates the protocols for classifying greenhouse gas (GHG) emissions. Scope 1 GHG emissions cover direct emissions from owned or controlled sources by the firm. Scope 2 GHG emissions cover indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the reporting company. Scope 3 GHG emissions include all other indirect emissions that occur in a company's value chain. Scope 1 emissions are fully controlled by the firm, while scope 3 emissions are less in the firms' control. The scope 3 emissions can be further divided into the upstream and downstream emissions based on the supply chain. Because the scope 3 total downstream emission data start in 2017, I only study the upstream for scope 3 emissions.

2.1 Data Release Lag

The timing of the conditioning variables has been a key research choice in studying the relation between the accounting variables and stock returns. Sufficient lags in the accounting variables need to be included to ensure that the accounting variables are known before the returns they are used to explain, that is, the information is in investors' information set. For example, Fama and French (1992) match the accounting data for all fiscal year-end in calendar year t-1 with the returns for July of year t to June of t+1. Jensen, Kelly and Pedersen (2022) use the most recent accounting data based on announcement dates. The choice varies more in the studies on the pricing of the carbon or ESG performance, ranging from contemporaneous regression (Aswani, Raghunandan and Rajgopal, 2022; Bolton and Kacperczyk, 2021; Garvey, Iyer and Nash, 2018), to 0 month lag in Bolton and Kacperczyk (2022) , 3 month lag in Pedersen, Fitzgibbons and Pomorski (2021), 6 month lag in Lindsey, Pruitt and Schiller (2021) and 9 month lag in Hsu, Li and Tsou (2022).[1]

S&P Trucost adds a new company-year observation to the database after companies complete their fiscal years and relevant data is publicly disclosed. Trucost then conducts a continuous research process as more coverage is made available. The research process is common across the data vendors. While most databases do not provide the date when the carbon emission data is made available, Trucost updates various environmental variables simultaneously and provides a date when the final data is made available.

Two observations arise. First, Trucost reviewed and updated the data prior to 2008 in May 2009. As such, all data points prior to 2008 are backfilled. Second, the data is updated with significant lags compared to other sources of data, such as the accounting variables. Figure 2 plots the histogram of the lag between the fiscal-year end and the date when the carbon data is made available for the fiscal year of 2008 and onward. The 25th percentile of the U.S. distribution is 6 months, the typical lag of the accounting variables, and the median is 10 months. The distribution has a long right tail, with the 75th percentile of 24 months. For the international sample, the 25th, 50th, and 75th percentiles are 7, 12, and 22 months,

[1] A number of studies use E, or S, and G ratings provided by the data vendors, which are updated monthly but subject to revisions by the data vendors (Berg, Fabisik and Sautner, 2020).

respectively. The data lag compares favorably with the other data vendors. For example, for the July 2021 download of the MSCI ESG data, the coverage for fiscal year of 2020 is 5% that of the 2019 for the U.S., 16% for the international sample. In this paper, I use the actual release date of the carbon emissions.

2.2 Sample and Summary Statistics

The final sample is the intersection between the monthly stock return data and annual carbon emissions data, ensuring that the carbon data is available before the stock return is known. The final matched sample covers the returns from June 2016 to December 2021. The key measure of the carbon-transition risk is carbon intensities, that is carbon emissions scaled by the fiscal year-end sales for the fiscal year. I consider a few alternative variables, including log carbon emissions and log year-on-year change of carbon emissions proposed in BK, and log carbon emissions scaled by market equity. If the latest carbon data for the latest fiscal year is not released yet, I fill the missing variables, emissions, growth, or carbon intensities, with the latest available number. For the international sample, I follow Hou, Karolyi and Kho (2011) to screen the international stock returns to minimize the impact of outliers.

Table 1 presents the distribution of headquarter countries and regions of firms as well as the summary statistics of average firm-level carbon intensity.[2] The U.S. firms represent most observations in the sample (22.8%), followed by Japan (13.6%) and China (8.3%). All nominal variables are denominated in U.S. dollars.

Table 2 presents the summary statistics of firm-level carbon measures and controls for the U.S, which is the main sample that I benchmark against the existing studies. The controls include the beta estimated over 60-month rolling window, size calculated as log year-end market capitalization, (log) book-to-market, momentum, ROA, asset growth, and leverage. For the carbon performance, the scope 3 carbon intensity is the highest among the three scopes of carbon intensities (mean 4.6), and the scope 1 and 2 both have a mean of 2.71. The scope 1 carbon intensity exhibits the highest variations with a standard deviation of 2.19,

[2]The average carbon intensity is calculated using all available data points in the sample and covers different sample periods for different countries.

compared to 1.40 and 1.03 for scope 2 and 3. The carbon intensities are persistent, with annual autocorrelations of 0.99, 0.93 and 0.95 for the scope 1, 2, and 3 measures, respectively. I winsorize all controls at 1% and 99% of the distribution.

3 The U.S. Evidence

In this section, I study the relation between the carbon-transition risk and stock returns.

3.1 Baseline Methodology

I construct quintile portfolios sorted on firms' carbon intensity, carbon emissions, and log carbon emission growth, respectively. At month t, I adopt the most recent available carbon emission data, calculate the carbon intensity by scaling the sales in the same year, total emissions, and the year-by-year emission growth, and then sort them into the quintile portfolios.[3] Thus, the low portfolio contains firms with the lowest carbon footprint and the high portfolio contains firms with the highest carbon footprint. After forming the five portfolios, I calculate the value-weighted monthly returns on these portfolios at time $t+1$. To examine the relation between the carbon footprint and returns, I also form a high-minus-low portfolio that takes a long position in the high-carbon portfolio and a short position in the low-carbon portfolio, and calculate the value-weighted return on this long-short portfolio.[4]

The empirical literature on the sustainable finance has adopted various test designs. Many studies also use equal-weighted portfolio returns. The smaller stocks, such as micro-caps, represent a small fraction of the market but a dis-proportionally fraction in the number of stocks. Blume and Stambaugh (1983) and Asparouhova, Bessembinder and Kalcheva (2013) show that microstructure frictions, such as bid-ask spreads and non-synchronous trading, can bias cross-sectional monthly mean equal-weighted returns, but has minimal impact

[3]While the carbon emission data is inherently an annual series, the portfolios are updated monthly as new data becomes available.

[4]I conduct robustness analysis using the NYSE breakpoints. Because the carbon data is better disclosed and estimated for the larger firms, the results are almost identical using the full sample or NYSE breakpoints. I opt for the full sample breakpoints in this setting for simplicity.

on the value-weighted returns.

A few studies also use the regressions of returns on carbon footprint or ESG scores, such as Fama-MacBeth (1973) or panel regressions. I use portfolio sorts for several reasons. First, the regressions are often performed with ordinary least squares, and they are often dominated by the smaller stocks in the number of observations. Inherently, the ordinary least squares is an equal-weighted approach, analogous to the equal-weighted portfolio sorts and are subject to the same biases. Second, because regressions impose a linear functional form between average returns and anomaly variables, they are more susceptible to outliers, volatile returns and values of explanatory variables, which most likely belong to smaller stocks. The nonparametric portfolio sorts instead do not impose such a linear functional form and allow for non-linearity in the return relation. As such, I use the value-weighted portfolio sorts as the main methodology. I replicate the regression-based results in section 3.4 and analyze the differences.

3.2 Baseline Results

Panel A of Table 3 presents the monthly average returns from the portfolio sorts for the scope 1, 2, and 3 carbon intensities, respectively. The carbon intensities can help predict the stock returns. For the scope 1 carbon intensities, the low, 2, 3, 4, and high portfolios earn a return of 1.48%, 1.35%, 1.48%, 1.39%, and 0.96% per month, respectively. More importantly, the high-minus-low portfolio generates a significant excess return of -0.52% per month. The pattern is similar for the scope 2 carbon intensities. The low, 2, 3, 4, and high portfolios earn a return of 1.54%, 1.48%, 1.25%, 1.44%, and 1.00% per month, respectively. The high-minus-low portfolio generates a significant excess return of -0.54% per month. In comparison, there is no significant long-short excess return for portfolios sorted on the scope 3 carbon intensity. Figure 3 further plots the cumulative returns of a strategy which longs the high portfolio and shorts the low portfolio. Over the sample period, the portfolio loses as much as 50% of its initial value, suggesting a cumulative return of 100% for the green (low-minus-high) portfolio over the sample period. Overall, the result shows that carbon intensities can help predict stock returns.

Panel B and C further conduct portfolio sorts for total emissions and total emission growth. The long-short spreads between the high and low portfolios are small and insignificant. In sum, the analysis shows that the carbon intensity is strongly associated with green premium in the U.S., while the total carbon emissions and emission growth do not explain the subsequent stock returns.

As a final comment in this section, the carbon intensity is calculated as the log of carbon emissions scaled by sales. One potential concern of the measure is that the carbon emissions are not closely related to sales. As a result, the predictability sources from the numerator, sales, instead of carbon emissions. First, I regress the log carbon emissions on log sales in the Internet Appendix and find log sales explain as much as 49%, 70%, and 82% variations in the three scopes of the carbon emissions. The coefficients are 1.03, 1.03, and 1.05, respectively. The coefficients are statistically indistinguishable to unity for the scope 1 and 2 at the 5% significance level, suggesting that the linear relation between carbon emissions and sales is a plausible assumption. Second, I adjust for the factor exposures in the next section to purge out the predictability that potentially arises from the denominator.

3.3 Asset Pricing Factor Analysis

This section investigates whether the variation in the average returns of the carbon intensity-sorted portfolios can be explained by existing risk factors. Firms can adopt a business model or use carbon offsets to lower emissions, which also reduces firms' profitability (Hsu, Li and Tsou, 2022). To account for this endogenous choice, I use the FF6 factor models (Fama and French, 2018), which includes the profitability factor together with the market, size, value, asset growth, and momentum factors.

Table 4 presents the results. Panel A shows that the long-short spread between the high and low carbon-intensity stocks loads on a number of risk factors. The long-short carbon intensity portfolio loads negatively on the market factor and positively on the size. The portfolio loads positively and especially strongly on the profitability factor, consistent with the conjecture above.[5]

After controlling for various factors, the more carbon-intensive stocks earn significantly lower alphas than the less carbon-intensive stocks. The portfolios sorted by the scope 1 carbon intensities earn abnormal returns of 0.2%, 0.03%, 0.11%, 0.03% and -0.28% per month, and the long-short alpha is -0.48% and significantly negative. Panel B and C show that the long-short portfolio alphas sorted by scope 2 and 3 carbon intensities are -0.57% (t-statistics = -2.75) and -0.38% (t-statistics = -1.95).

The Internet Appendix presents the portfolio alphas adjusted using the CAPM model, alternatively, and the results are similar. Furthermore, the Internet Appendix presents the factor-adjusted alphas for the portfolios sorted by carbon emissions and carbon emission growth and finds no alphas for the long-short portfolios, consistent with the univariate analysis. In short, the carbon intensity contains significant explanatory power for subsequent stock returns, while the total carbon emissions and carbon emission growth do not help explain future stock returns.

3.4 Regression Analysis

In this section, I first replicate the results in BK and then show that the look-ahead bias and equal-weighted panel regression overstates the carbon premium in data. First, I regress the monthly stock returns on the contemporaneous carbon variables and lagged firm-level controls as in Table 8 of BK (2021),

$$r_{it} = \alpha + \beta Carbon_{it} + \gamma Controls_{it-1} + \nu_t + \varepsilon_{it}, \tag{10}$$

The regression is at the firm-month level and controls for the time fixed effects. The standard errors are doubly clustered at the firm and monthly level, accordingly. I standardize the carbon measures are have zero mean and unit variance throughout the regressions such

[5]The portfolio also loads positively strongly on the investment factor. This can arise because firms are yet to transition to the new net zero economy or the brown firms are spending on the green investments as part of the transition, which the model does not allow for.

that the coefficients can be interpreted as the change in the monthly stock returns for a one-standard-deviation increase in the carbon footprint.

Table 5 presents the results. Consistent with BK, carbon emissions and carbon emission growth are significantly positively associated with contemporaneous stock returns, but the carbon intensity is not. Note that the year t carbon emissions are unknown to the firm or investors in year t, but contains substantial accounting information about the company, e.g., sales. The regression thus shows that the cash flow shocks, proxied by carbon emissions, are associated with contemporaneous stock returns.

Second, I regress the monthly stock returns in year $t+1$ on the carbon variables in year t and lagged firm-level controls as in Table 6 of BK (2022) in the U.S. sample. Note that the accounting controls are used after the data is announced by the firm, and the carbon emissions enter the regression under the assumption of a zero-month release lag. Because the carbon data are often released with significantly lags with a median of 10 months, the regression is again a contemporaneous regression for carbon emissions. Panel B shows that the total carbon emissions again explain stock returns, with similar coefficients as in Panel A but less significance. Neither the emission growth or carbon intensity can explain stock returns. The coefficients associated with scope 1, 2, and 3 carbon emission growth decreases from 0.24, 0.21, and 0.38 to the negative range, -0.01, -0.03, and 0.06.

Next, Panel C regresses the monthly stock returns on the "true" lagged carbon measures in investors' information set and lagged controls,

$$r_{it} = \alpha + \beta Carbon_{it-1} + \gamma Controls_{it-1} + \nu_t + \varepsilon_{it}. \tag{11}$$

The regression is at the firm-monthly level and controls for the time fixed effects. The standard errors are doubly clustered at the firm and monthly level, accordingly. After accounting for the reporting lags, the carbon emissions do not explain future stock returns. The coefficients associated with the carbon intensity and carbon emission growth become more negative. In fact, the scope 2 carbon emissions now negatively predict the stock returns with a coefficient of -0.20 (t statistic=-2.26).

As discussed in section 3.1, the regressions with the ordinary least squares are often dominated by smaller stocks because of their plentifulness and in fact assign even more weights on smaller stocks than equal-weighted portfolio sorts. I now account for this issue in the regression framework by running the same regression as in the Panel C, but as a weighted-least-squares regression weighted by the firm size. This approach corrects for the over-weighting in the small stocks, but still imposes a linear relation between the returns and carbon variables. Panel D shows that the carbon intensity now significantly negatively explains the future stock returns. A one-standard-deviation increase in the scope 1, 2, and 3 carbon intensity is associated with a decrease of -0.25%, -0.25%, and -0.19% in future stock returns per month, respectively. The magnitudes are comparable to the portfolio-sorted spreads. Total emissions also predict future stock returns negatively and significantly for the scope 1. Finally, the emission growth does not predict stock returns, and the point estimates are all negative. In sum, after accounting for the data release lag and value weighting, there is a significant green return associated with the carbon intensity.

3.5 Robustness

This section now returns to the baseline sorting and conducts a few robustness analysis. First, most climate performance measures are estimated by Trucost instead of reported by the firms. More than half of the scope 1 and 2 emissions are estimated by the data vendor, more than 90% of scope 3 carbon emissions are estimated by the data vendor. I now study the subsample in which the scope 1 and 2 emissions are reported by the firms only. Table 6 reports the raw returns of the sorted portfolios and the return spread between the high and low portfolios. The return spreads are -0.44% and -0.50% for the scope 1 and 2 carbon intensities, respectively. Adjusting for the FF6 factors, the alphas of the return spreads are -0.41% and -0.54%. In sum, there is a strong green return associated with the reported emissions and the results are similar to the full sample.

Second, I study alternative scalars for calculating carbon intensities, e.g. the market equity as in Ilhan, Sautner and Vilkov (2021). Panel B shows that the sorted portfolio returns are strongly monotonically decreasing. The raw high-minus-low return spreads are -0.49%, -0.42%, and -0.43%, respectively. After adjusting for the factor exposures, the excess returns are -0.43%, -0.48%, and -0.49%, respectively.

After that, I compare the importance of the industry-level and firm-level carbon intensities. For example, Pástor, Stambaugh and Taylor (2022) prefer the gross firm-level greeness, Ilhan, Sautner and Vilkov (2021) highlight the role of industry-level greenness in markets, and BK emphasize the within-industry firm-level measures. I conduct the sorts with the industry-level carbon intensities and the within-industry firm-level residuals. The industry-level carbon intensity is calculated as the log ratio of total carbon emissions to the total sales in each GICS4 industry. The firm-level residual is the difference between the firm-level and industry-level carbon intensity. Panel A of Table 7 finds significant green raw returns with scope 1 measures and green alphas with both the scope 1 and 2 measure. The scope 1 and 2 alphas are -0.54% and -0.48%, respectively, comparable to the unadjusted baseline alphas. Furthermore, Panel B finds that the firm-level carbon intensities have little predictability for the stock returns. In sum, the predictability sources mostly from the industry-level carbon intensities.

4 International Evidence

This section now turns to the international markets and examines whether the carbon intensity can help explain future stock returns internationally. International stock markets are economically important in terms of the market capitalization that they represent. They also help provide out-of-sample evidence and guard against potential data snooping bias.

I conduct the portfolio sorting as in section 4.1 for each country, but use terciles to ensure enough stocks in each portfolio. Figure 4 plots the long-short portfolio excess returns sorted by the carbon intensities and the 95th confidence interval. The figure shows large differences in the excess returns. In fact, the excess returns are negative for roughly half of the sample. Overall, the carbon intensities do not significantly predict stock returns.

The baseline international results uses the long-short raw returns. As the U.S. evidence shows, the carbon returns can load on a number of risk factors. I thus now adjust for asset pricing factors by running a time series regression for each country,

$$r_{it} = \alpha + \beta factors_{it} + \varepsilon_{it}. \tag{12}$$

where r_{it} is the long-short carbon return and $factors_{it}$ denotes the FF6 factors for each region or country, including the U.S., North America excluding the U.S., Europe, Japan, Asia Pacific excluding Japan, and other countries as emerging markets. This approach allows the factor returns or loadings to vary across countries and allows for imperfectly integrated international markets (Fama and French, 2017).

Figure 5 plots the portfolio alphas across countries for various carbon intensities. The map reveals little consistence in the portfolio alphas. Instead, the portfolio alphas vary substantially across countries. For example, the U.S. stands as a country with positive green alphas (-0.4%, -0.34%, and -0.34%), and China has positive brown alphas instead (0.53%, 0.23%, and 0.42%).

To test whether average excess return is significantly different from zero statistically, I regress the raw returns and alphas on a constant in pool regressions across countries. Table 8 presents the results. First, the tercile-sroted U.S. long-short carbon returns are significantly negative for the scope 1 and 2 carbon intensities, consistent with the quintile-sorted baseline result. The spreads are -0.39% and -0.27%. Second, I pool the international long-short returns together and run a pooled regression (Column "All"). The average excess return is small and insignificant for both the raw returns and alphas, consistent with the visual impression. In other words, the strong green return based on carbon intensities only exists in the U.S. stock market, but not internationally. In the remainder of the paper, I explore potential reasons for this finding.

I first split the international sample into groups of countries. I start with G7 (excluding the U.S.) and Australia, which contains developed countries that are most comparable to the U.S. The excess raw returns associated with the scope 1, 2, and 3 carbon intensities are -0.25%, -0.16%, and -0.11%, respectively, much more comparable to the U.S. return. The alphas are -0.39%, -0.3% and -0.36%, statistically significant for all three scopes of carbon intensities. Second, I split the international sample into the develop and emerging markets (DM and EM) and find more negative carbon returns in the DM countries in general. For example, the carbon alphas for the DM countries are -0.3%, -0.19% and -0.31% for the three scopes of carbon intensities, respectively. The carbon alphas for the EM countries are positive, 0.16%, 0.13% and 0.07%, respectively.

5 What Drives Cross-Country Carbon Return Variations?

In equilibrium, the brown firms face higher carbon-transition risk and earn higher expected returns to compensate investors for taking on the additional carbon risk as shown in section 1. Empirically, the carbon premium is largely missing from in-sample returns in the U.S. and internationally. The carbon return varies significantly across countries. One possible interpretation of the results is that investors do not really care about the carbon risk. Instead, the carbon or green premium in the U.S. is merely a result of data mining and arises from a statistical coincidence. An alternative interpretation is that investors have started taking into account the carbon risk, but as investors' preference shifts takes place, the in-sample carbon return can be negative. As investors' attention and preference differ across countries, the carbon return also varies across countries. The following section explains the cross-country variations in the carbon returns.

5.1 Sustainable Flow and Climate Concern

Pástor, Stambaugh and Taylor (2021) propose that as the economy shifts to be carbon-aware, the shift of the investor preference can constitute in-sample shocks and generate superior in-sample green return. The analysis above shows that the more developed countries, such as the U.S., other G7 countries and Australia, tend to earn a green return in the recent sample. The question naturally follows whether the relation between green return and development levels sources from the correlation between development and in-sample shocks. I consider two sources of in-sample shocks. First, investors' preference for green assets can increase, driving up green asset prices. I measure the shift by the country-level sustainable investor flows each quarter scaled by the end-of-quarter market capitalization.[6] The sustainable flow is highly correlated with the log GDP per capita, with a coefficient of 0.47.

Second, consumers' demands for green products can strength, driving up green firms' profits and thus their stock prices. I proxy the cumulative shift in consumer demand by the level of climate concerns from the Lloyd's Register Foundation 2019 World Risk Poll. The survey asks whether the interviewees perceive the climate change as a very serious threat, a somewhat serious threat, or not a threat at all. The climate concern is the total fraction who answers a very serious and somewhat serious threat. Because the climate change only started concerning the public in recent years, the measure climate concern proxy for the cumulative increase in the climate concern in recent years. The climate concern is also highly correlated with the log GDP per capita, with a coefficient of 0.43.

I examine the relation between the abnormal green or carbon returns and preference shifts in the following regression

$$r^s_{it} = a + b \cdot \mathrm{X}_{it-1} + \nu_t + e_{it}, \tag{13}$$

where the abnormal carbon return $r^s_{it} = \alpha + \varepsilon_{it}$ is calculated from the regression (12). X_{it-1} denotes the lagged country characteristics, such as the log GDP per capita or sustainable flow, or a snapshot of country characteristics. The variables Xs are standardized to have zero mean and unit variance each fiscal year (or year-quarter) such that the measure captures the cross-sectional variations. The coefficient b can be interpreted as the increase in the carbon return associated a one-standard-deviation increase in X. The regression includes monthly fixed effects. The standard errors are doubly clustered at the country and monthly level,

[6] The data is obtained from the report "Passive Sustainable Funds: The Global Landscape 2020" published by the Morningstar. The data on the active sustainable flows are only available for a subset of countries from 2016 onward. The correlation between the active and passive sustainable flows are highly correlated, with a coefficient of 0.93.

unless the X is only a snapshot of country characteristics and I in turn cluster the standard errors at the monthly level.

Table 9 presents the results. Consistently with the hypothesis, the carbon return is significantly negatively associated with the log GDP per capita, sustainable flow, and climate concern. For example, a one-standard-deviation increase in the log GDP per capita is associated with a 0.31%, 0.28%, and 0.35% decrease in the carbon return per month for the scope 1, 2, and 3 carbon intensities, respectively. For the demand shifts, a one-standard-deviation increase in the sustainable flow is associated with a decrease of 0.19%, 0.19%, and 0.16%. For the climate news, a one-standard-deviation increase in the climate concern is associated with a decrease of 0.11%, 0.10%, and 0.12%. The coefficients are significant for the scope 1 and 3 measures. The magnitudes are economically large enough to explain the strong green premium in the U.S. as well as the strong carbon premium in China.

Column 4 of the table conducts a multivariate regression with all three measures. In the multivariate regression, the coefficients on the log GDP per capita become closer to zero than the univariate coefficient. The coefficients associated with the sustainable flow are most significant among the three country-level measures for the scope 1 and 2. The coefficients on the climate concerns are insignificant because the surveyed cross-sectional measure is most noisily measured and the standard errors are double clustered at the country and monthly level. The R^2s of the regressions are comparable to the individual univariate regressions, suggesting that the three variables capture similar information. In sum, the shifts in investor and consumer preference drive sizable variations in the carbon return variations across countries. In particular, the developed countries have experienced stronger shifts and exhibit stronger green premium. The less developed countries instead exhibit stronger brown premium.

5.2 Variations in Expected Returns

The previous analysis studies the impact of in-sample shocks on the carbon returns. The carbon return also contains an expected return component, which captures the carbon risk premium. This section studies variations in the hidden risk premium component after controlling for the climate-related preference shifts.

5.2.1 Exposure to Climate Change

The risk premium can vary with the country-level exposure to climate change. Because the countries that are more exposed to climate change bear more externality of carbon emissions, investors in these countries can require a higher risk premium associated with the climate change and carbon risk. I use two measures of exposures to climate change. First, Nordhaus (1991) show that the agriculture sector is most vulnerable to climate change, and I measure the economic exposure to climate change using the log fraction of agriculture in GDP. Second, climate scientists have found that the trend increase in global temperatures exacerbates the risks of droughts. The impact significantly varies across countries, with many potentially adversely affected while some might actually benefit (Trenberth et al., 2014). I follow Hong, Li and Xu (2019) to proxy for the exposure of the country by the long-term trend toward droughts using the Palmer Drought Severity Index (PDSI trend).

Table 10 presents the results. I control for the preference shifts, measured by the log GDP per capita, sustainable flow, and climate concern in all specifications. Consistent with the hypothesis, the countries that are more exposed to climate change earn higher carbon return. Take the scope 1 intensity for example, a one-standard-deviation increase in the agriculture fraction and palmer trend is associated with a significant increase of 0.14% and 0.19% in the monthly carbon returns. In particular, the R^2s almost doubles in the regression with the palmer trend compared to the regression without it, suggesting that the physical risk drives sizable carbon return variations across countries. In sum, the carbon return is significantly higher in countries that are more vulnerable to climate change.

5.2.2 Climate Policy

The carbon-transition risk can also be increasing in the country-level climate policy tightness. Policies are subject to change, and investors expect significantly more policies coming into shape in the future years.[7] However, the current policy provides useful guidance about future policy stringency regarding decarbonization. As such, countries with more stringent current policies are more likely to require higher expected carbon returns.

I measure the policy tightness using the policy score in Climate Change Performance Index (formerly known as Germanwatch). Columns 3 of Table 10 shows that countries with more stringent climate policies have higher carbon returns in general. A one-standard-deviation increase in the climate policy tightness is associated with a increase of 0.12%, 0.09%, and 0.08% in the monthly carbon return for scope 1, 2, and 3 carbon intensities, respectively. The effect is most statistically and economically significant for the scope 1 carbon return.

5.2.3 Other Characteristics

Finally, I study a number of additional country characteristics that are often discussed in the public press or literature. First, I study the reliance of the economy on carbon emissions. Specifically, I measure the industry structure, that is the log fraction of manufacturing the economy, and the growth rate of the GDP. Column 4 and 5 of Table 10 find that after controlling for in-sample shocks, the measures cannot explain significant variations in carbon returns.

Second, I study the socio-political conditions, measured by the governance score provided by Worldwide Governance Indicators. The measure is a combination of six aspects, voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption. For example, BK (2022) hypothesizes that countries with better governance in general is likely to have more stable climate policies and require lower expected carbon return. Column 6 finds no support for the hypothesis.

Overall, the green premium in the U.S. and the variations across countries are less likely

[7] The detailed climate policies are yet to be fleshed out in most countries, leaving much room for the policy uncertainty, and adding to the transition risk of brown firms. By 2021, a total of 131 countries have committed to reducing net carbon emissions to zero, but just six have enshrined that commitment in law.

to be a result of data mining. Instead, the shifts in investor preferences and climate concern are important drivers of the cross-country variations. The strong shifts in the more developed countries generate stronger green returns in these countries. After controlling for these in-sample shocks, countries with higher exposure to climate change or tighter climate policies have higher carbon returns.

6 Conclusion

The science broadly agrees that the reduction in carbon emissions is required to fight climate change and avoid catastrophic consequences. By December 2021, 236 asset managers with 57.5 trillion U.S. dollars asset under management have joined the net zero asset management initiative (NZAM), which commits to support the goal of net zero greenhouse gas ("GHG") emissions by 2050. However, the practitioners and academics heatedly debate about whether investors materially care about the carbon risk in their investments.

As the regulations and social atmosphere turns against the brown firms, the brown firms would need higher required rate of return to compensate investors for the increased carbon-transition risk. The carbon premium as well as the measures of the carbon-transition risk have been the focus of several recent influential studies. This paper shows that, after accounting for the data release lag and with value weighting, less carbon-intensive firms deliver higher returns in the U.S., while there is no excess return associated with total carbon emissions and emission growth. The international evidence on carbon premium is also largely absent.

Further analysis shows that the green premium in the U.S. and the variations across countries are less likely to be a result of data mining. Instead, the shifts in investor preferences and climate concerns are important drivers of the cross-country variations. The strong shifts in the more developed countries generate stronger green returns in these countries. In sum, the evidence shows that the transition to the new equilibrium with full carbon awareness is aggressively underway globally.

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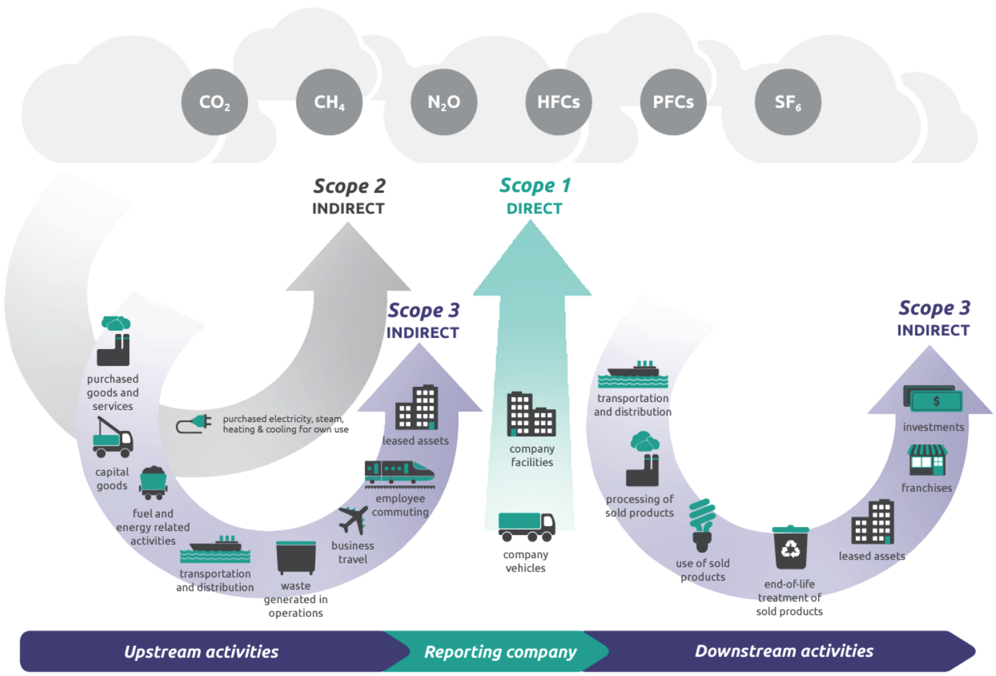
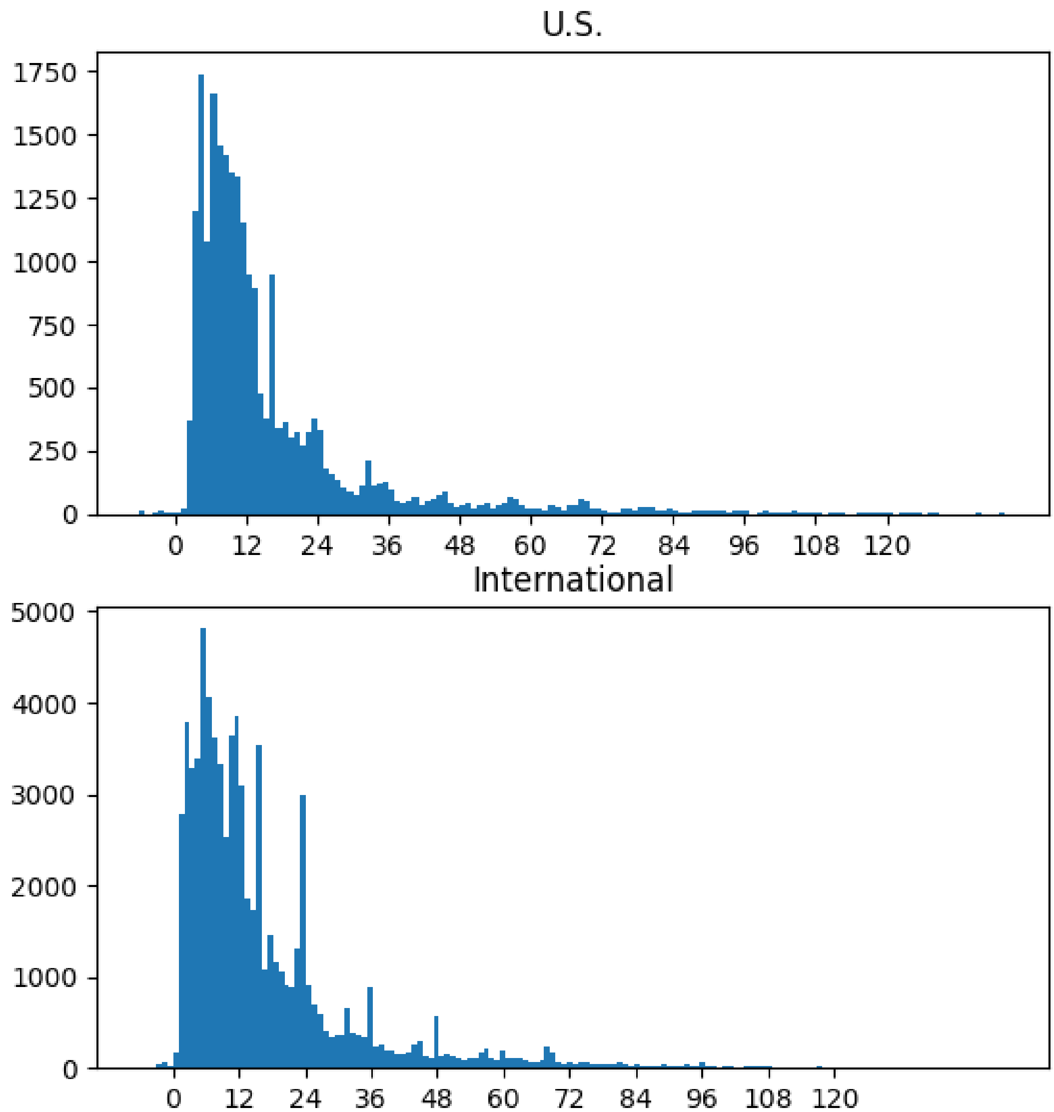
Figure 1: GHG Protocol Scopes and Emissions Across the Value Chain



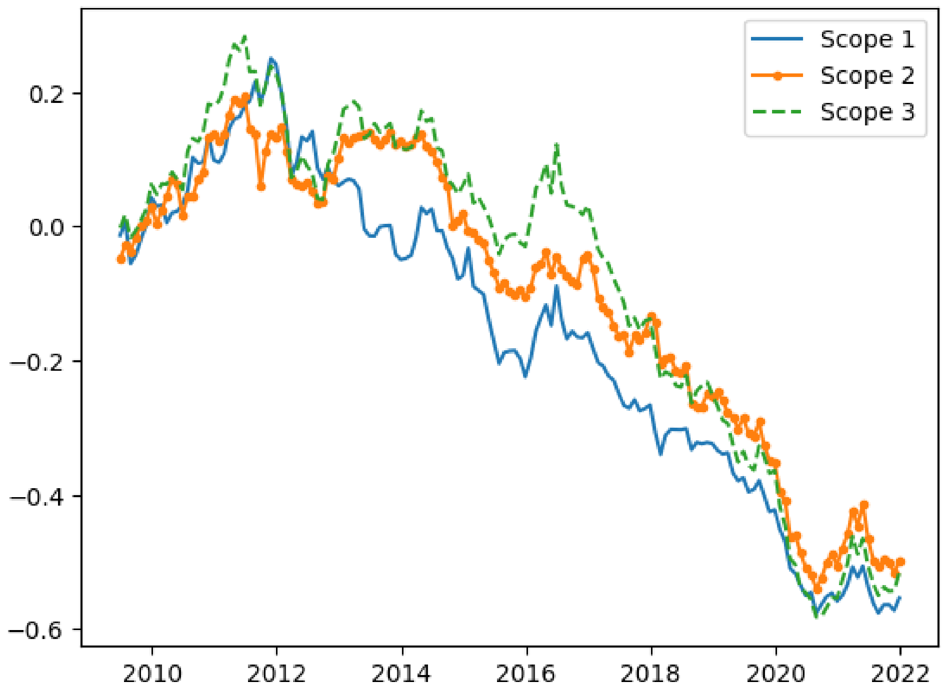
Source: WRI/WBCSD Corporate Value Chain Accounting and Reporting Standard.

Figure 2: Reporting Lags



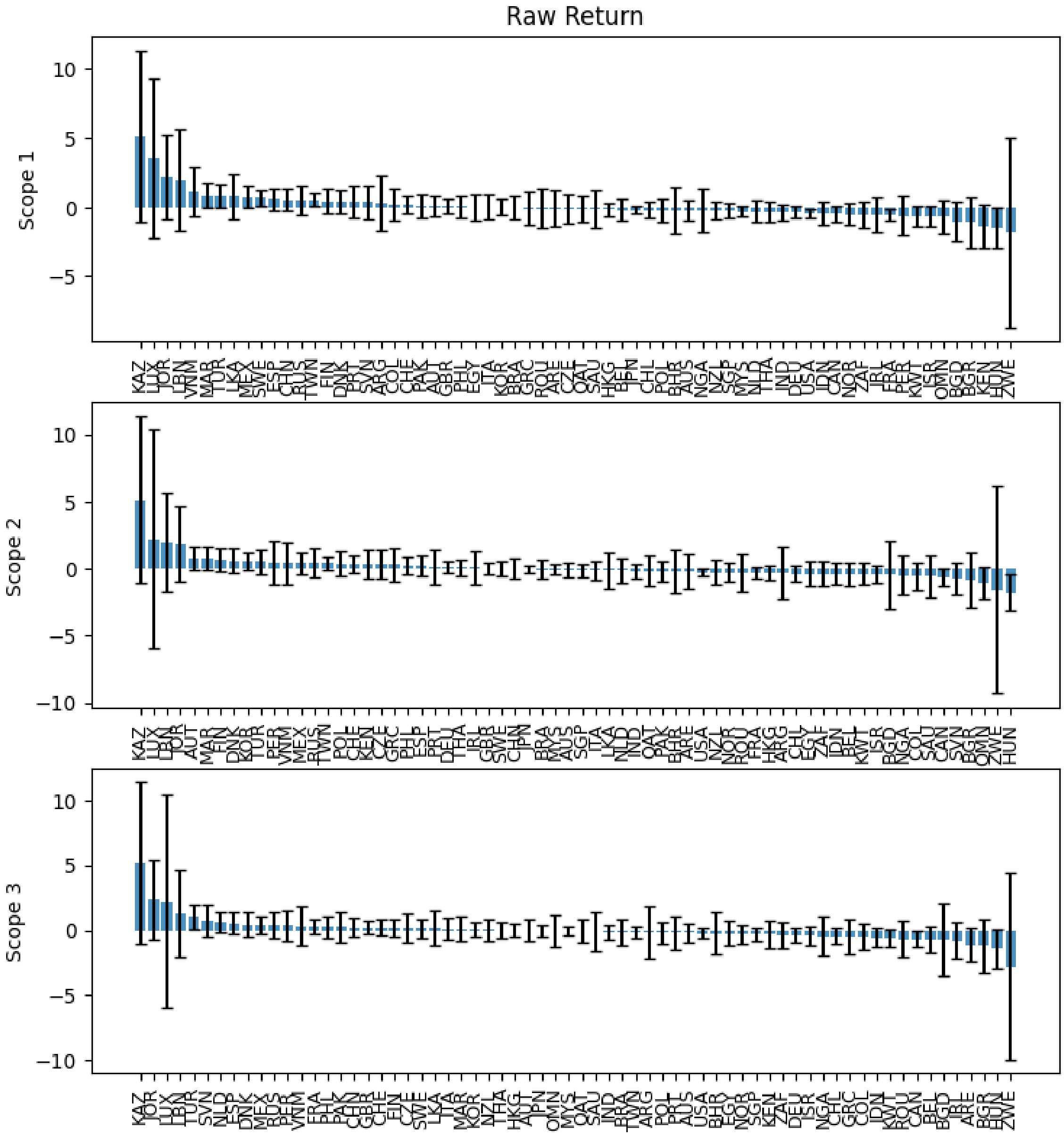
Notes: This figure plots the tabulation of reporting lags for scope 1 carbon emissions for the U.S. and international sample.

Figure 3: U.S. Cumulative Excess Green Return



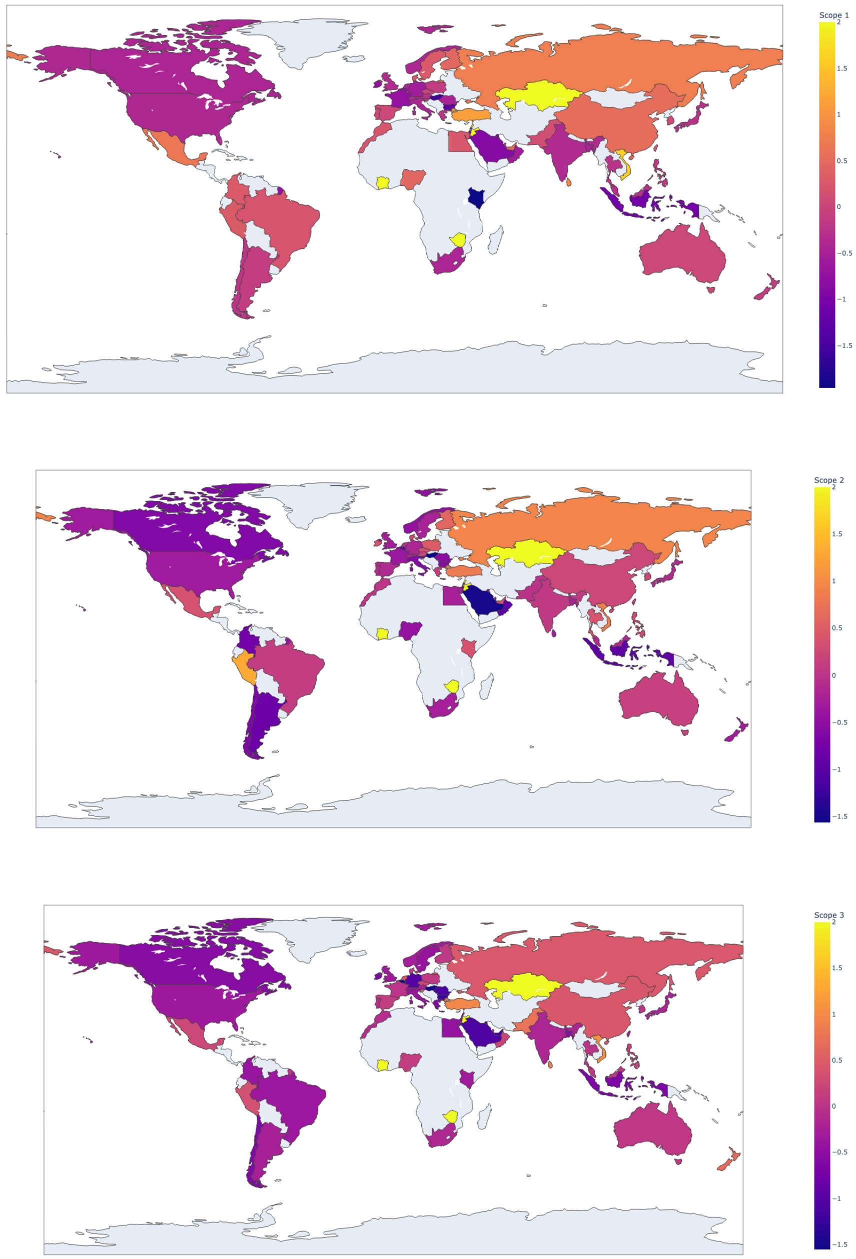
Notes: This figure plots the cumulative return of the return spread between the high and carbon intensity portfolio.

Figure 4: Country-Level Sorting



Notes: This figure plots the raw return spread between the high and low carbon intensity portfolios for each country. The raw returns are in percentage points and the black bands denote the 95% confidence interval.

Figure 5: Country-Level Alphas



Notes: This figure plots the FF6-adjusted return spread between the high and low carbon intensity portfolios for each country. The alpha spreads are in percentage points and the black bands denote the 95% confidence interval.

Table 1: Summary Statistics by Country

			Carbon Intensity		
Country	Observations	Min Year	Scope 1	Scope 2	Scope 3
ARE	1,899	2009	2.37	2.72	4.19
ARG	1,097	2009	3.60	2.85	4.71
AUS	31,817	2009	3.20	3.33	4.61
AUT	3,427	2009	3.45	2.87	4.70
BEL	5,019	2009	2.97	2.90	4.51
BGD	427	2015	3.47	3.06	5.02
BGR	266	2015	3.33	3.16	4.44
BHR	291	2015	0.19	1.42	3.32
BMU	28	2019	-0.16	0.10	3.17
BRA	7,834	2009	3.13	2.30	4.72
BWA	17	2020	-0.55	-0.30	2.78
CAN	24,264	2009	3.50	3.13	4.57
CHE	15,528	2009	2.28	2.38	4.68
CHL	4,055	2009	3.46	2.20	4.24
CHN	56,034	2009	3.68	3.21	4.97
CIV	169	2015	2.36	2.75	4.90
COL	1,033	2009	3.94	1.88	4.74
CYP	32	2019	0.04	1.06	2.91
CZE	862	2009	2.75	2.38	4.68
DEU	18,753	2009	2.83	2.85	4.73
DNK	4,047	2009	2.82	2.39	4.88
EGY	3,454	2009	3.52	3.04	4.81
ESP	6,842	2009	2.72	2.46	4.60
EST	129	2015	4.10	3.39	4.18
FIN	5,250	2009	2.87	2.89	5.05
FRA	22,018	2009	2.54	2.52	4.59
GBR	52,609	2009	2.44	2.67	4.51
GHA	128	2015	3.49	3.39	6.37
GRC	2,602	2009	3.41	2.94	4.77
HKG	43,381	2009	3.35	3.24	4.79
HRV	237	2009	2.65	3.39	4.18
HUN	468	2009	2.34	2.42	4.00
IDN	8,352	2009	3.53	2.98	4.74
IND	30,181	2009	3.54	2.81	4.90
IRL	1,567	2009	3.82	3.17	5.25

ISR	7,171	2009	2.60	2.78	4.25
ITA	8,573	2009	2.88	2.62	4.72
JAM	44	2018	-0.14	1.23	3.42
JOR	386	2015	1.84	2.37	4.06
JPN	131,104	2009	3.01	3.06	4.91
KAZ	157	2014	1.09	0.85	3.15
KEN	823	2012	2.44	1.41	3.86
KOR	53,121	2009	3.29	3.12	5.10
KWT	1,163	2009	1.62	2.31	3.82
LBN	219	2015	0.74	2.24	2.86
LKA	582	2009	2.54	2.88	4.43
LTU	158	2015	2.07	3.21	4.10
LUX	166	2013	-0.90	1.40	2.79
MAR	1,385	2009	4.27	3.74	5.06
MEX	5,181	2009	3.20	3.27	4.90
MUS	96	2015	-0.08	1.08	2.70
MYS	13,941	2009	3.58	2.96	4.89
NAM	83	2015	2.64	3.79	3.63
NGA	1,643	2011	2.68	2.36	4.74
NLD	4,990	2009	2.51	2.43	4.59
NOR	6,558	2009	3.29	2.25	4.86
NZL	2,846	2009	3.05	2.38	4.51
OMN	777	2010	2.11	1.85	3.75
PAK	4,247	2009	4.36	2.84	5.07
PER	1,629	2009	4.14	3.72	4.82
PHL	4,693	2009	3.87	3.10	4.66
POL	5,615	2009	3.08	2.79	4.54
PRT	1,831	2009	3.23	2.88	4.59
QAT	1,918	2014	2.90	2.48	4.12
ROU	338	2014	3.14	1.39	4.65
RUS	3,896	2009	4.94	2.92	4.90
SAU	2,439	2018	3.64	3.30	4.86
SGP	9,681	2009	3.13	3.24	4.47
SRB	12	2015	-0.15	-0.32	2.70
SVN	404	2009	2.41	2.93	4.15
SWE	9,282	2009	2.02	2.47	4.56
THA	8,462	2009	3.31	2.89	4.66
TUN	162	2015	-0.27	-0.19	2.88
TUR	7,146	2009	3.78	3.12	4.92

TWN	47,442	2009	3.31	3.28	5.09
UKR	84	2015	4.53	3.48	4.73
USA	211,470	2009	2.71	2.71	4.60
VNM	1,107	2012	3.22	2.64	4.91
ZAF	12,857	2009	2.96	3.88	4.65
ZWE	169	2016	4.09	3.89	5.89

Notes: This table presents the sample frequency and average scope 1, 2, and 3 firm-level carbon intensities by country.

Table 2: Summary Statistics for the U.S. Sample

	AR	Mean	SD	P50	P25	P75
Scope 1 Intensity	0.99	2.71	2.19	2.71	1.40	3.61
Scope 2 Intensity	0.93	2.71	1.40	2.82	2.04	3.65
Scope 3 Intensity	0.95	4.60	1.03	4.59	3.79	5.40
Scope 1 Emissions	0.98	10.08	3.06	10.16	8.07	11.91
Scope 2 Emissions	0.97	10.08	2.53	10.30	8.64	11.74
Scope 3 Emissions	0.98	11.97	2.39	12.20	10.48	13.63
Scope 1 ΔEmissions	0.00	0.04	0.48	0.03	-0.06	0.14
Scope 2 ΔEmissions	0.00	0.06	0.56	0.03	-0.06	0.16
Scope 3 ΔEmissions	-0.01	0.05	0.35	0.04	-0.05	0.13
Beta	0.87	1.23	0.63	1.15	0.81	1.55
Size	1.01	7.97	1.68	8.01	6.83	9.15
Book-to-Market	0.85	-0.88	0.94	-0.76	-1.40	-0.25
ROA	0.72	0.00	0.15	0.03	0.00	0.07
Asset Growth	0.10	0.11	0.29	0.05	-0.02	0.14
Momentum	0.00	0.16	0.48	0.10	-0.11	0.33
Leverage	0.73	3.98	4.45	1.75	4.01	
Sales Growth	-0.04	0.05	0.33	0.04	-0.03	0.12
EPS Growth	-0.28	0.16	2.73	0.23	-0.36	0.70

Notes: This table reports summary statistics of the variables used for regressions. The carbon intensity is calculated as the log ratio of the total carbon emissions to the year-end sales. The autocorrelations (AR) are calculated at the annual frequency. Size is the log year-end market equity; beta is estimated over a 60-month rolling window; the (log) book-to- market ratio is the log of book value of equity divided by market value of equity; ROA is the net income scaled by total assets; asset growth is the percentage change of total assets; momentum is the past 12-month return skipping the most recent month; leverage is the book leverage defined as the book value of debt divided by the book value of assets, and sales and EPS growth are the log year-by-year growth of the sales and EPS.

Table 3: Univariate Portfolio Sorting

	L	2	3	4	H	H-L
	Panel A: Carbon Intensities					
Scope 1	1.48***	1.35***	1.48***	1.39***	0.96**	-0.52**
	(3.72)	(4.19)	(4.34)	(4.19)	(2.56)	(-2.27)
Scope 2	1.54***	1.48***	1.25***	1.44***	1.00***	-0.54***
	(4.36)	(4.01)	(3.69)	(4.44)	(2.62)	(-2.65)
Scope 3	1.22***	1.60***	1.38***	1.37***	1.12***	-0.10
	(2.75)	(4.81)	(4.24)	(3.81)	(3.16)	(-0.39)
	Panel B: Total Emissions					
Scope 1	1.31***	1.76***	1.33***	1.46***	1.18***	-0.12
	(3.29)	(4.50)	(3.37)	(4.20)	(3.74)	(-0.56)
Scope 2	1.11***	1.56***	1.54***	1.48***	1.25***	0.14
	(2.98)	(4.12)	(4.20)	(3.97)	(3.78)	(0.63)
Scope 3	1.37***	1.48***	1.45***	1.40***	1.31***	-0.06
	(3.05)	(3.59)	(3.92)	(3.63)	(4.11)	(-0.19)
	Panel C: Total Emission Growth					
Scope 1	1.35***	1.25***	1.26***	1.43***	1.49***	0.14
	(3.92)	(3.90)	(3.58)	(3.96)	(3.91)	(0.77)
Scope 2	1.38***	1.21***	1.32***	1.43***	1.41***	0.03
	(3.91)	(3.60)	(3.87)	(3.98)	(3.80)	(0.14)
Scope 3	1.22***	1.39***	1.30***	1.43***	1.35***	0.13
	(3.27)	(4.33)	(3.79)	(4.15)	(3.48)	(0.60)

Notes: This table presents the monthly value-weighted raw returns of the carbon footprint-sorted portfolios. The sorting variables are carbon intensity, total emissions, and log emission growth, respectively. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table 4: Asset Pricing Factor Test

			Panel A: Scope 1			
	L	2	3	4	H	H-L
α	0.20*	0.03	0.11	0.03	-0.28**	-0.48**
	(1.67)	(0.45)	(1.08)	(0.23)	(-2.09)	(-2.13)
MKT	1.11***	0.96***	0.99***	0.96***	0.95***	-0.16***
	(36.45)	(49.18)	(38.29)	(33.19)	(27.47)	(-2.73)
SMB	-0.25***	0.01	0.00	0.05	0.12**	0.37***
	(-4.78)	(0.33)	(0.02)	(0.98)	(2.00)	(3.72)
HML	0.27***	-0.12***	-0.13***	-0.25***	0.22***	-0.05
	(4.97)	(-3.40)	(-2.92)	(-4.88)	(3.62)	(-0.45)
RMW	-0.36***	0.06	0.11*	0.12**	0.14*	0.51***
	(-5.55)	(1.43)	(1.88)	(1.98)	(1.93)	(4.09)
CMA	-0.20**	0.11**	0.13*	0.22***	0.15	0.35**
	(-2.34)	(2.00)	(1.86)	(2.76)	(1.57)	(2.18)
MOM	-0.05	0.04*	-0.00	0.01	-0.06	-0.01
	(-1.37)	(1.80)	(-0.15)	(0.31)	(-1.41)	(-0.12)
R^2	0.93	0.95	0.93	0.90	0.89	0.20
Observations	151	151	151	151	151	151
			Panel B: Scope 2			
α	0.23*	0.16*	-0.01	0.07	-0.33***	-0.57***
	(1.91)	(1.84)	(-0.11)	(0.87)	(-2.78)	(-2.75)
MKT	1.00***	1.07***	0.98***	0.97***	0.99***	-0.02
	(32.72)	(48.82)	(48.71)	(46.78)	(32.41)	(-0.35)
SMB	-0.06	-0.09**	-0.07**	0.00	0.19***	0.26***
	(-1.22)	(-2.50)	(-2.15)	(0.01)	(3.71)	(2.88)
HML	0.03	0.10**	0.05	-0.15***	0.12**	0.08
	(0.60)	(2.52)	(1.36)	(-3.98)	(2.17)	(0.91)
RMW	0.02	-0.24***	-0.00	0.14***	0.20***	0.18
	(0.30)	(-5.06)	(-0.00)	(3.07)	(3.09)	(1.62)
CMA	-0.11	-0.10	-0.05	0.34***	0.15*	0.26*
	(-1.33)	(-1.59)	(-0.93)	(5.87)	(1.73)	(1.79)
MOM	-0.01	0.02	-0.06**	0.05*	-0.07*	-0.07
	(-0.14)	(0.79)	(-2.29)	(1.82)	(-1.92)	(-1.04)
R^2	0.90	0.96	0.96	0.95	0.92	0.18
Observations	151	151	151	151	151	151

			Panel C: Scope 3			
α	0.14	0.25***	0.01	0.02	-0.24**	-0.38*
	(1.18)	(2.76)	(0.08)	(0.13)	(-2.03)	(-1.95)
MKT	1.04***	0.99***	0.97***	1.00***	0.99***	-0.06
	(34.17)	(43.72)	(43.47)	(32.95)	(33.63)	(-1.17)
SMB	-0.07	-0.06*	-0.05	0.12**	0.03	0.10
	(-1.28)	(-1.66)	(-1.32)	(2.30)	(0.56)	(1.14)
HML	0.72***	-0.13***	-0.28***	-0.02	0.05	-0.67***
	(13.40)	(-3.22)	(-7.00)	(-0.31)	(0.96)	(-7.77)
RMW	-0.45***	0.09*	0.11**	0.09	0.22***	0.67***
	(-6.80)	(1.76)	(2.28)	(1.32)	(3.49)	(6.32)
CMA	-0.53***	-0.10	0.32***	0.12	0.26***	0.79***
	(-6.26)	(-1.59)	(5.09)	(1.48)	(3.23)	(5.83)
MOM	-0.07*	0.04	-0.04	0.02	-0.01	0.05
	(-1.83)	(1.29)	(-1.51)	(0.42)	(-0.38)	(0.91)
R^2	0.94	0.94	0.94	0.91	0.91	0.50
Observations	151	151	151	151	151	151

Notes: This table presents the monthly alphas of the carbon intensity-sorted portfolios. The alphas are obtained by regressing the raw returns on the FF6 factors. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table 5: U.S. Regression Analysis

	Panel A: Contemporaneous Regressions								
	Intensity			Emissions			Growth		
	Scope 1	2	3	1	2	3	1	2	3
Scope 1	-0.02			0.11			0.24***		
	(-0.28)			(1.35)			(5.62)		
Scope 2		0.06			0.22**			0.21***	
		(0.94)			(2.20)			(4.55)	
Scope 3			0.09			0.29***			0.38***
			(1.57)			(2.72)			(5.53)
Log PPE	0.01	-0.01	-0.02	-0.04	-0.06	-0.08	-0.03	-0.03	-0.03
	(0.24)	(-0.21)	(-0.43)	(-0.82)	(-1.06)	(-1.39)	(-0.58)	(-0.58)	(-0.50)
Beta	0.14	0.12	0.13	0.14	0.10	0.11	0.17	0.17	0.17
	(0.71)	(0.67)	(0.68)	(0.70)	(0.52)	(0.59)	(0.84)	(0.87)	(0.85)
Size	-0.15	-0.12	-0.11	-0.11	-0.15	-0.16	-0.01	-0.01	-0.02
	(-1.55)	(-1.34)	(-1.18)	(-1.26)	(-1.50)	(-1.63)	(-0.12)	(-0.15)	(-0.21)
Book-to-Market	-0.09	-0.06	-0.05	-0.08	-0.06	-0.08	-0.12	-0.13	-0.10
	(-0.80)	(-0.47)	(-0.43)	(-0.65)	(-0.50)	(-0.64)	(-1.12)	(-1.18)	(-0.93)
ROA	-0.35	-0.33	-0.33	-0.33	-0.48	-0.58	-0.50	-0.51	-0.44
	(-0.48)	(-0.43)	(-0.44)	(-0.44)	(-0.63)	(-0.77)	(-0.65)	(-0.67)	(-0.58)
Asset Growth	0.03	0.02	0.03	0.02	0.04	0.05	0.05	0.05	-0.03
	(0.25)	(0.20)	(0.21)	(0.18)	(0.30)	(0.43)	(0.40)	(0.45)	(-0.26)
Momentum	0.11	0.12	0.12	0.13	0.15	0.14	0.11	0.11	0.06
	(0.40)	(0.46)	(0.44)	(0.49)	(0.56)	(0.51)	(0.40)	(0.40)	(0.22)
Leverage	-0.00	0.01	0.01	0.01	0.01	0.01	-0.00	-0.00	-0.00
	(-0.04)	(0.38)	(0.54)	(0.36)	(0.45)	(0.40)	(-0.26)	(-0.30)	(-0.18)
Sales Growth	-0.36**	-0.35**	-0.35**	-0.36**	-0.35**	-0.35**	-0.50**	-0.50**	-0.59***
	(-2.16)	(-2.09)	(-2.05)	(-2.13)	(-2.11)	(-2.11)	(-2.39)	(-2.36)	(-2.74)
EPS Growth	-0.05*	-0.05*	-0.05*	-0.05*	-0.04*	-0.04*	-0.05**	-0.05**	-0.05**
	(-1.90)	(-1.90)	(-1.89)	(-1.88)	(-1.78)	(-1.74)	(-2.07)	(-2.05)	(-2.05)
R^2	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20
Observations	240930	240930	240925	241153	241153	241148	216649	216649	216644
	Panel B: 0-Month Lag								
Scope 1	-0.11			0.03			-0.01		
	(-1.21)			(0.24)			(-0.39)		
Scope 2		0.06			0.24*			-0.03	
		(0.74)			(1.73)			(-0.88)	
Scope 3			0.00			0.24*			0.06
			(0.00)			(1.74)			(0.85)
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
R^2	0.18	0.18	0.18	0.18	0.18	0.18	0.20	0.20	0.20
Observations	244138	244138	244127	244173	244173	244162	217274	217274	217263

	Panel C: Forward-Looking Regressions								
	Intensity			Emissions			Growth		
	Scope 1	2	3	1	2	3	1	2	3
Scope 1	-0.12			0.03			-0.08		
	(-1.18)			(0.20)			(-1.19)		
Scope 2		0.02			0.22			-0.20**	
		(0.19)			(1.36)			(-2.26)	
Scope 3			-0.10			0.19			-0.14
			(-1.26)			(1.12)			(-1.22)
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
R^2	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Observations	166768	166768	166768	166768	166768	166768	159760	159760	159757
	Panel D: Forward-Looking Weighted Regression								
Scope 1	-0.25***			-0.41***			0.02		
	(-2.93)			(-3.21)			(0.22)		
Scope 2		-0.25***			-0.24			-0.05	
		(-2.89)			(-1.58)			(-0.48)	
Scope 3			-0.19**			-0.16			-0.03
			(-2.08)			(-0.93)			(-0.23)
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
R^2	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Observations	166768	166768	166768	166768	166768	166768	159760	159760	159757

Notes: This table reports the results of regressing stock returns on log carbon intensities, log carbon emissions, and log carbon emission growth. Panel A conducts the contemporaneous regression of the t stock returns on the t carbon footprint and lagged controls. Panel B conducts a regression of the t stock returns on the $t-1$ carbon footprint and lagged controls. Panel C conducts a regression of the t stock returns on the lagged carbon footprint after the carbon data is released and lagged controls. Finally, Panel D conducts a weighted least square version of the regression as in Panel C. The regressions control for time fixed effects and the standard errors are double clustered the firm and time level. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table 6: Robustness Analysis

	L	2	3	4	H	H-L
Panel A: Firm-Reported Emissions Only						
A.1. Raw Returns						
Scope 1	1.46***	1.38***	1.43***	1.37***	1.02***	-0.44*
	(3.64)	(4.31)	(4.21)	(4.06)	(2.70)	(-1.84)
Scope 2	1.52***	1.47***	1.28***	1.39***	1.02***	-0.50**
	(4.30)	(3.94)	(3.78)	(4.26)	(2.67)	(-2.43)
A.2. Alphas						
Scope 1	0.18	0.07	0.07	-0.00	-0.23	-0.41*
	(1.45)	(0.87)	(0.67)	(-0.03)	(-1.60)	(-1.73)
Scope 2	0.22*	0.15	0.01	0.03	-0.32***	-0.54**
	(1.75)	(1.61)	(0.11)	(0.34)	(-2.65)	(-2.59)
Panel B: Alternative Sorting Variable: Emissions/ME						
B.1. Raw Returns	L	2	3	4	H	H-L
Scope 1	1.50***	1.46***	1.36***	1.15***	1.01***	-0.49**
	(3.82)	(4.71)	(4.00)	(3.22)	(2.68)	(-2.10)
Scope 3	1.60***	1.42***	1.27***	1.22***	1.18***	-0.42*
	(4.53)	(4.11)	(3.76)	(3.56)	(2.96)	(-1.81)
Scope 3	1.52***	1.41***	1.31***	1.36***	1.08***	-0.43*
	(3.90)	(4.26)	(3.81)	(4.14)	(2.64)	(-1.72)
B.2. Alphas						
Scope 1	0.19*	0.19**	-0.03	-0.18*	-0.24*	-0.43**
	(1.78)	(2.14)	(-0.40)	(-1.77)	(-1.82)	(-2.01)
Scope 2	0.23*	0.18**	-0.05	-0.05	-0.25**	-0.48**
	(1.86)	(2.33)	(-0.62)	(-0.55)	(-2.37)	(-2.58)
Scope 3	0.21*	0.10	-0.02	0.01	-0.28**	-0.49**
	(1.79)	(1.32)	(-0.29)	(0.10)	(-2.25)	(-2.41)

Notes: This table presents the monthly raw returns and alphas of the carbon footprint-sorted portfolios. The alphas are obtained by regressing the raw returns on the FF6 factors. Panel A focuses on the sample with the emissions reported by the firm only. Panel B uses an alternative sorting variables, that is carbon emissions scaled by year-end market equity. The sorting variables are carbon intensity, total emissions, and log emission growth, respectively. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table 7: Industry and Firm-level Analysis

	L	2	3	4	H	H-L
Panel A: Industry-level Analysis						
A.1. Raw Returns						
Scope 1	1.51***	1.38***	1.57***	1.13***	1.04***	-0.47**
	(4.26)	(4.08)	(4.07)	(3.10)	(2.81)	(-2.28)
Scope 2	1.27***	1.52***	1.50***	1.25***	1.14***	-0.13
	(3.30)	(4.36)	(4.19)	(3.84)	(2.83)	(-0.53)
Scope 3	1.39***	1.51***	1.45***	1.26***	1.18***	-0.21
	(3.57)	(4.63)	(4.24)	(3.05)	(3.46)	(-0.87)
A.2. Alphas						
Scope 1	0.29***	0.01	0.10	-0.16	-0.25	-0.54***
	(3.15)	(0.09)	(0.65)	(-1.20)	(-1.56)	(-2.72)
Scope 2	0.18	0.13	0.13	-0.08	-0.30*	-0.48**
	(1.60)	(1.10)	(1.02)	(-0.64)	(-1.70)	(-2.02)
Scope 3	0.15	0.22**	0.04	-0.15	-0.12	-0.27
	(1.53)	(1.98)	(0.28)	(-0.89)	(-0.78)	(-1.28)
Panel B: Within-Industry Firm-level Analysis						
B.1. Raw Returns						
	L	2	3	4	H	H-L
Scope 1	1.35***	1.42***	1.39***	1.34***	1.28***	-0.07
	(3.40)	(4.18)	(3.89)	(4.13)	(3.77)	(-0.43)
Scope 2	1.62***	1.28***	1.29***	1.27***	1.36***	-0.26*
	(4.67)	(3.60)	(3.74)	(3.63)	(3.95)	(-1.66)
Scope 3	1.27***	1.31***	1.24***	1.55***	1.31***	0.04
	(3.28)	(3.83)	(3.65)	(4.56)	(3.69)	(0.29)
B.2. Alphas						
Scope 1	-0.02	0.08	0.08	0.06	0.03	0.04
	(-0.14)	(0.99)	(0.86)	(0.58)	(0.28)	(0.26)
Scope 2	0.28**	-0.08	0.02	-0.07	0.06	-0.22
	(2.22)	(-1.10)	(0.21)	(-0.80)	(0.68)	(-1.33)
Scope 3	-0.06	0.01	-0.04	0.17*	-0.01	0.04
	(-0.56)	(0.17)	(-0.56)	(1.94)	(-0.13)	(0.28)

Notes: This table presents the monthly raw returns and alphas of the industry-level and firm-level sorted portfolios, based on the industry-level carbon intensities and within-industry firm-level carbon intensities. The alphas are obtained by regressing the raw returns on the FF6 factors. Panel A conducts sorts using the industry-level carbon intensities, and Panel B uses the within-industry firm-level carbon intensities. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table 8: International Carbon Returns

	U.S.	All	G7 + AUS	DM	EM
Panel A: Raw Returns					
Scope 1	-0.39**	0.02	-0.25**	-0.08	0.08
	(-2.47)	(0.22)	(-2.36)	(-1.02)	(0.75)
Scope 2	-0.27*	0.03	-0.16	-0.01	0.05
	(-1.87)	(0.38)	(-1.62)	(-0.10)	(0.48)
Scope 3	-0.23	-0.03	-0.11	-0.07	-0.00
	(-1.32)	(-0.36)	(-0.90)	(-0.77)	(-0.00)
Panel B: FF6 Alphas					
Scope 1	-0.40***	-0.02	-0.39***	-0.30***	0.16*
	(-2.78)	(-0.24)	(-4.20)	(-4.01)	(1.71)
Scope 2	-0.34***	0.00	-0.30***	-0.19***	0.13
	(-2.66)	(0.03)	(-3.39)	(-2.59)	(1.31)
Scope 3	-0.34**	-0.08	-0.36***	-0.31***	0.07
	(-2.38)	(-1.15)	(-3.40)	(-3.98)	(0.77)
Observations	151	8201	1057	3171	5030

Note: This table regresses the pooled regression of the sorted carbon excess returns on a constant. Panel A uses the raw excess returns and Panel B uses the factor-adjusted returns. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table 9: Sustainable Flow and Climate Concern

	(1)	(2)	(3)	(4)
	Panel A: Scope 1			
GDP Per Capita	-0.31**			-0.15
	(-2.21)			(-1.36)
Sustainable Flow		-0.19*		-0.16
		(-1.89)		(-1.44)
Climate Concern			-0.11*	0.03
			(-1.75)	(0.36)
R^2	0.04	0.04	0.04	0.05
Observations	8118	7367	7789	6757
	Panel B: Scope 2			
GDP Per Capita	-0.28**			-0.09
	(-2.48)			(-0.94)
Sustainable Flow		-0.19**		-0.17**
		(-2.55)		(-2.02)
Climate Concern			-0.10	0.03
			(-1.49)	(0.24)
R^2	0.04	0.04	0.03	0.04
Observations	8118	7367	7789	6757
	Panel C: Scope 3			
GDP Per Capita	-0.35***			-0.24*
	(-2.89)			(-1.95)
Sustainable Flow		-0.16*		-0.11
		(-1.81)		(-1.30)
Climate Concern			-0.12*	0.07
			(-1.71)	(0.69)
R^2	0.05	0.04	0.05	0.05
Observations	8118	7367	7789	6757

Notes: This table reports the results of regressing stock returns on lagged carbon intensities and the interaction of lagged carbon intensities with lagged country characteristics. The country characteristics are the log GDP per capita, the ratio of sustainable flows to the stock market capitalization, and the surveyed climate concern from the World Risk Poll. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table 10: Exposure, Policy and Additional Country Characteristics

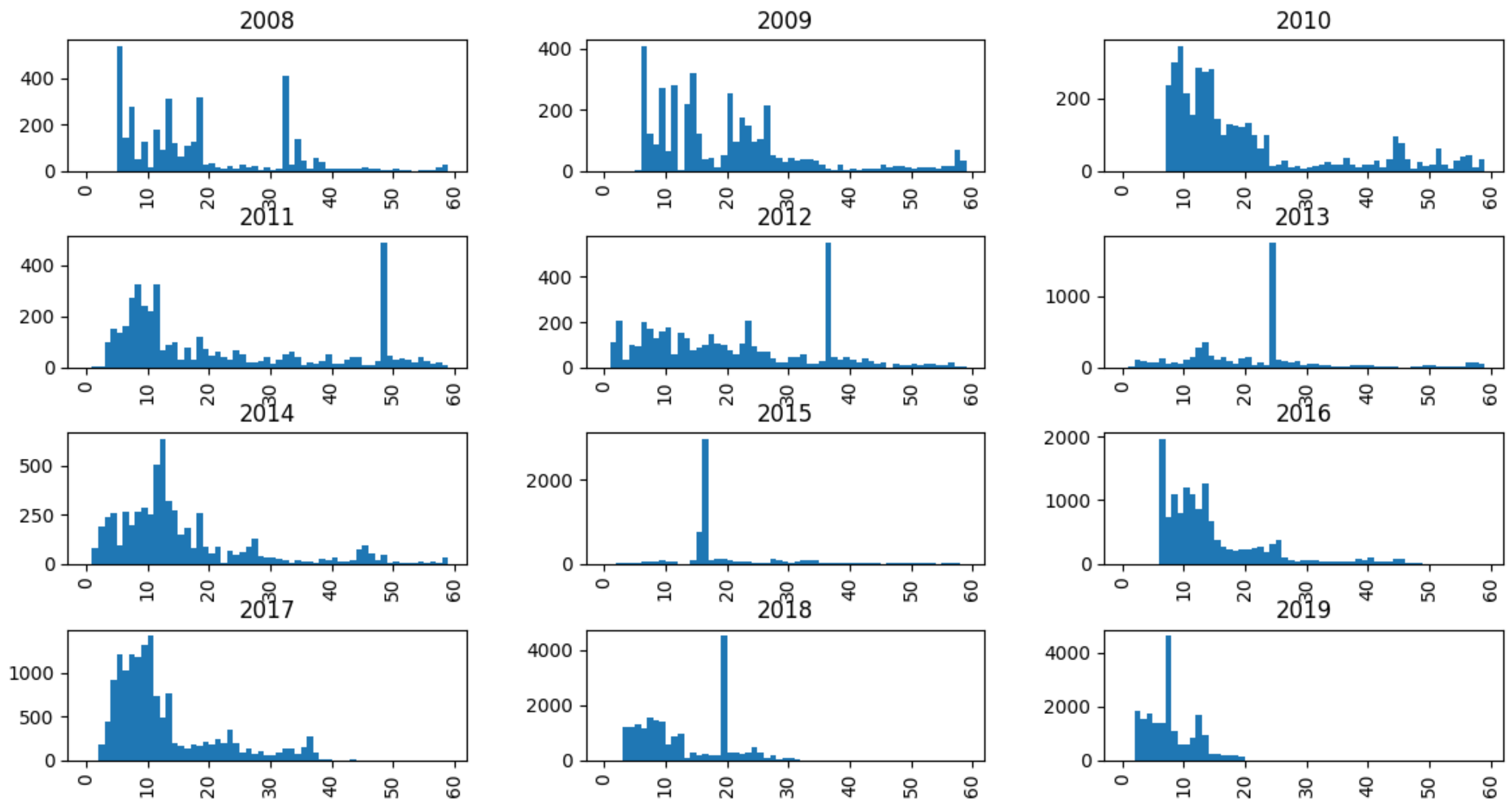
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A: Scope 1			
% Agriculture	0.14**					
	(2.35)					
PDSI Trend		0.19***				
		(2.79)				
Policy			0.12			
			(1.56)			
% Manufacturing				-0.03		
				(-0.28)		
GDP Growth					0.13	
					(0.66)	
Governance						-0.11
						(-0.61)
GDP Per Capita	-0.00	-0.14	0.02	-0.17	-0.13	-0.04
	(-0.02)	(-1.09)	(0.14)	(-1.41)	(-1.15)	(-0.15)
Sustainable Flow	-0.18	-0.10	-0.14	-0.13	-0.17	-0.16
	(-1.62)	(-0.95)	(-1.36)	(-1.23)	(-1.61)	(-1.45)
Climate Concern	0.04	0.14	-0.09	0.03	0.04	0.04
	(0.43)	(1.04)	(-0.75)	(0.31)	(0.47)	(0.42)
R^2	0.05	0.10	0.07	0.05	0.05	0.05
Observations	6727	4059	5104	6674	6757	6757
			Panel B: Scope 2			
% Agriculture	0.11					
	(1.59)					
PDSI Trend		0.04				
		(0.52)				
Policy			0.09			
			(1.16)			
% Manufacturing				0.01		
				(0.12)		
GDP Growth					0.13	
					(0.58)	
Governance						-0.02
						(-0.09)
GDP Per Capita	0.04	-0.18	0.19	-0.09	-0.06	-0.07
	(0.31)	(-1.20)	(1.20)	(-0.90)	(-0.58)	(-0.31)
Sustainable Flow	-0.20**	-0.07	-0.11	-0.18**	-0.19**	-0.18**
	(-2.16)	(-0.89)	(-1.24)	(-2.06)	(-2.24)	(-2.01)
Climate Concern	0.03	0.06	-0.18	0.03	0.03	0.03
	(0.30)	(0.36)	(-1.23)	(0.30)	(0.32)	(0.25)
R^2	0.04	0.07	0.05	0.04	0.04	0.04
Observations	6727	4059	5104	6674	6757	6757

	Panel C: Scope 3					
	(1)	(2)	(3)	(4)	(5)	(6)
% Agriculture	0.22**					
	(2.02)					
PDSI Trend		0.17**				
		(2.45)				
Policy			0.08			
			(1.21)			
% Manufacturing				-0.01		
				(-0.11)		
GDP Growth					0.18	
					(1.18)	
Governance						0.18
						(1.02)
GDP Per Capita	-0.01	-0.13	0.15	-0.26**	-0.21*	-0.44*
	(-0.05)	(-0.91)	(0.92)	(-2.16)	(-1.68)	(-1.99)
Sustainable Flow	-0.13	-0.09	-0.13	-0.08	-0.12	-0.10
	(-1.64)	(-1.06)	(-1.57)	(-1.03)	(-1.44)	(-1.31)
Climate Concern	0.08	-0.01	-0.19	0.08	0.08	0.06
	(0.79)	(-0.06)	(-1.68)	(0.69)	(0.81)	(0.61)
R^2	0.05	0.09	0.08	0.05	0.05	0.05
Observations	6727	4059	5104	6674	6757	6757

Notes: This table reports the results of regressing stock returns on lagged carbon intensities and the interaction of lagged carbon intensities with lagged country characteristics. The country characteristics are the log fraction of agriculture in the economy, the trend of the Palmer Drought Severity Index, the local climate policy tightness, the log fraction of manufacturing in the economy, the log GDP growth rate, and the country-level governance score, the log GDP per capita, the ratio of sustainable flows to the stock market capitalization, and the surveyed climate concern from the World Risk Poll. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

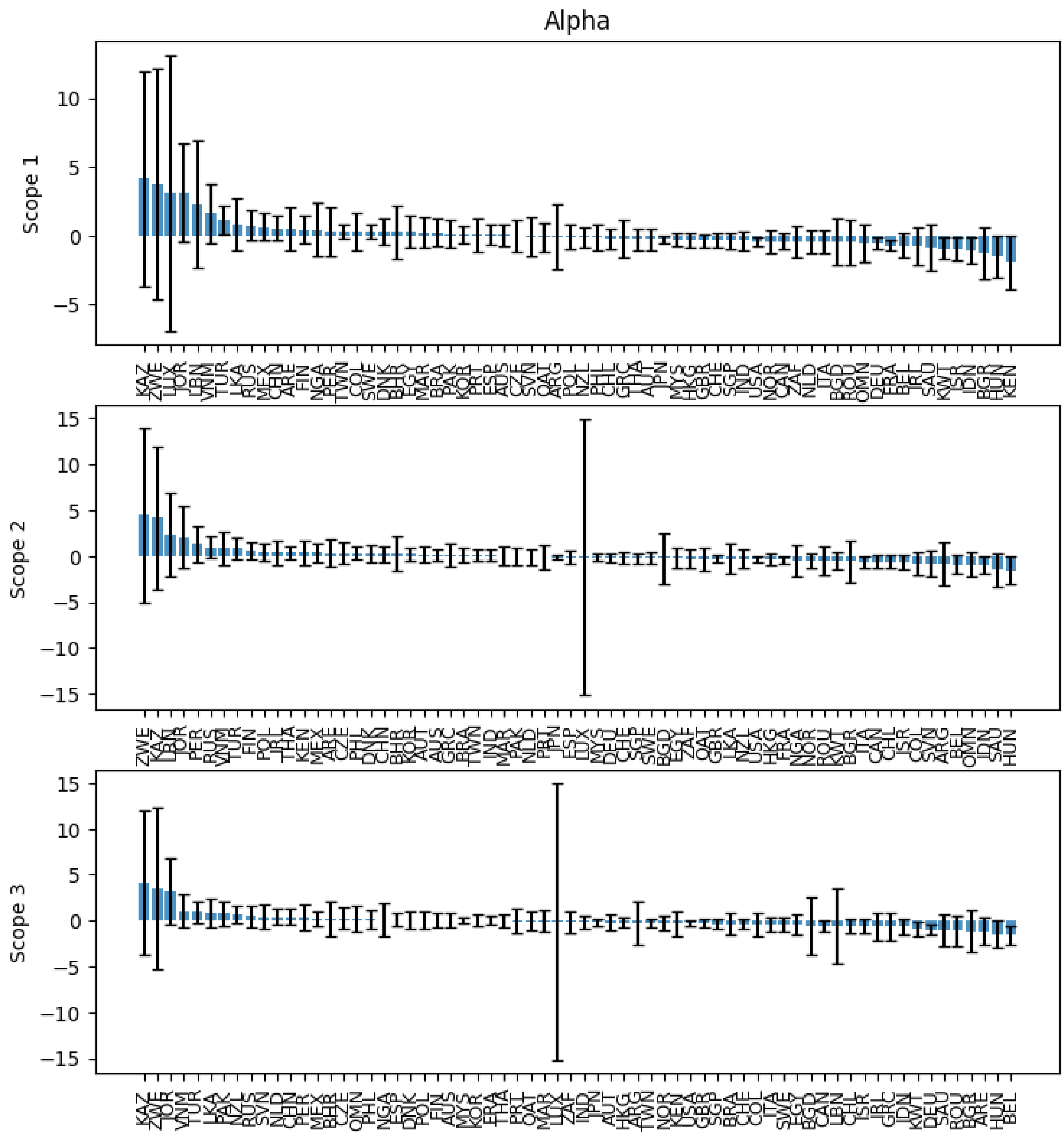
Internet Appendix to
"Carbon Premium: Is it There?"

Figure IA.1: Reporting Lags By Year



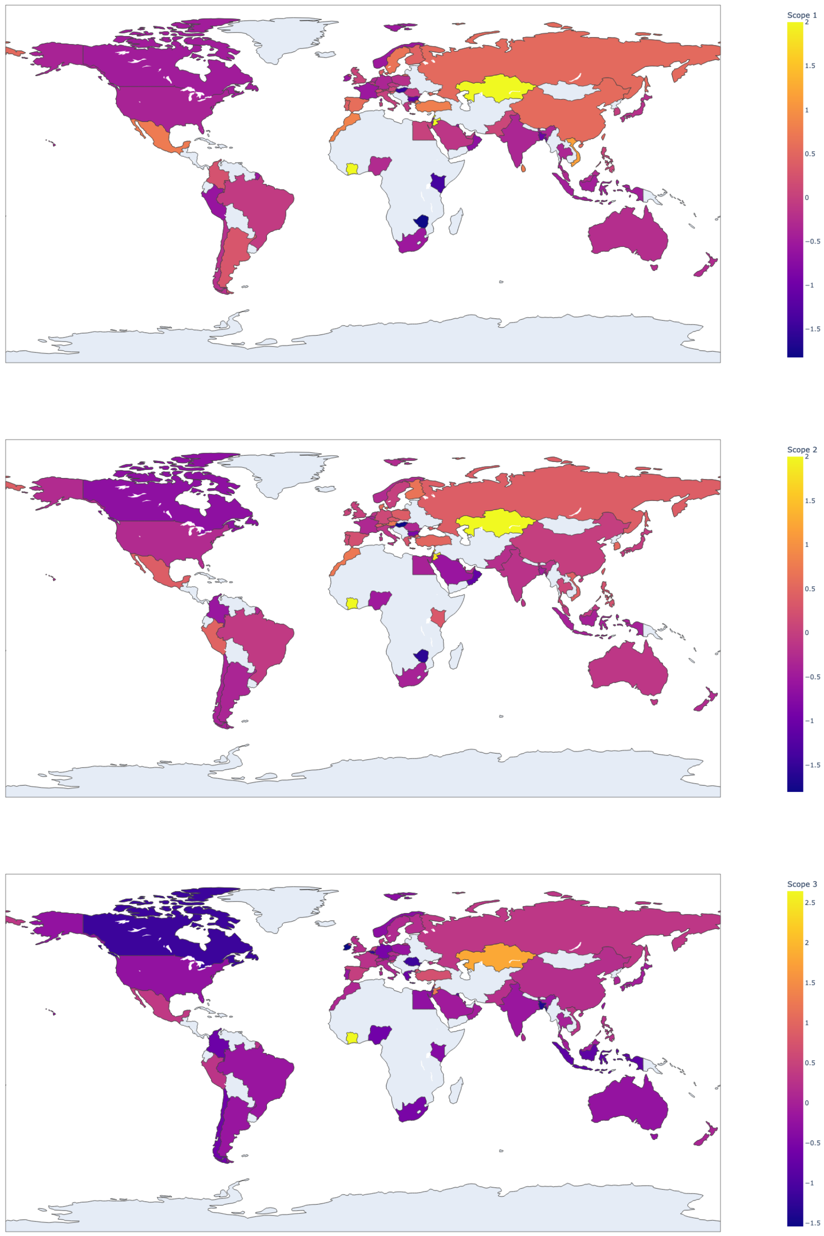
Notes: This figure plots the tabulation of reporting lags for scope 1 carbon emissions for the U.S. by year.

Figure IA.2: Country-Level Sorting



Notes: This figure plots the alpha return spread between the high and low carbon intensity portfolios for each country. The alphas are in percentage points and the black bands denote the 95% confidence interval.

Figure IA.3: Country-Level Raw Returns



Notes: This figure plots the raw return spread between the high and low carbon intensity portfolios for each country. The raw returns are in percentage points and the black bands denote the 95% confidence interval.

Table IA.1: Scales of Carbon Emissions

	Scope 1	2	3	Scope 1	2	3
Log Sales	1.03***	1.03***	1.05***			
	(44.93)	(75.81)	(98.18)			
Log PPE				1.04***	0.79***	0.79***
				(44.90)	(26.06)	(31.47)
R^2	0.49	0.70	0.82	0.63	0.56	0.65
Observations	21753	21753	21752	21508	21508	21507

Note: This table regresses log scope 1, 2, and 3 carbon emissions on the year-end log sales and log PPE. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table IA.2: Asset Pricing Factor Test: CAPM

	L	2	3	4	H	H-L
Panel A: Scope 1						
α	0.01	0.13	0.20**	0.17	-0.38**	-0.39
	(0.07)	(1.59)	(1.99)	(1.43)	(-2.43)	(-1.64)
MKT	1.12***	0.93***	0.97***	0.93***	1.02***	-0.10*
	(35.25)	(50.38)	(40.94)	(33.13)	(28.07)	(-1.77)
R^2	0.89	0.94	0.92	0.88	0.84	0.02
Observations	151	151	151	151	151	151
Panel B: Scope 2						
α	0.23**	0.08	-0.04	0.22**	-0.40***	-0.63***
	(1.98)	(0.85)	(-0.51)	(2.39)	(-2.89)	(-2.93)
MKT	0.99***	1.07***	0.98***	0.92***	1.06***	0.07
	(36.86)	(50.95)	(53.81)	(43.47)	(33.23)	(1.31)
R^2	0.90	0.95	0.95	0.93	0.88	0.01
Observations	151	151	151	151	151	151
Panel C: Scope 3						
α	-0.34*	0.36***	0.17	0.03	-0.18	0.15
	(-1.66)	(3.50)	(1.62)	(0.28)	(-1.48)	(0.61)
MKT	1.18***	0.94***	0.92***	1.02***	0.99***	-0.19***
	(25.12)	(40.30)	(38.62)	(37.47)	(34.36)	(-3.29)
R^2	0.81	0.92	0.91	0.90	0.89	0.07
Observations	151	151	151	151	151	151

Notes: This table presents the monthly CAPM alphas of the carbon footprint-sorted portfolios. The sorting variables are carbon intensity, total emissions, and log emission growth, respectively. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table IA.3: Factor Adjustment FF6 Alphas: Carbon Emissions and Carbon Emission Growth

Panel A: Total Emissions						
Scope 1	0.21*	0.43***	0.06	0.07	-0.13*	-0.34**
	(1.75)	(3.87)	(0.52)	(0.96)	(-1.68)	(-2.19)
Scope 2	0.14	0.35***	0.30***	0.06	-0.06	-0.20
	(0.85)	(2.86)	(3.04)	(0.56)	(-1.55)	(-1.19)
Scope 3	0.19	0.22*	0.22**	-0.02	0.01	-0.18
	(1.02)	(1.89)	(2.40)	(-0.29)	(0.27)	(-0.91)
Panel B: Total Emission Growth						
Scope 1	0.10	0.05	-0.02	0.05	0.01	-0.09
	(1.22)	(0.60)	(-0.21)	(0.60)	(0.04)	(-0.57)
Scope 2	0.12	0.02	0.02	0.10	-0.05	-0.18
	(1.38)	(0.26)	(0.21)	(1.16)	(-0.43)	(-0.96)
Scope 3	-0.04	0.09	0.02	0.12	-0.08	-0.03
	(-0.37)	(1.23)	(0.28)	(1.54)	(-0.63)	(-0.17)

Notes: This table presents the monthly FF6 alphas of the carbon footprint-sorted portfolios. The sorting variables are total emissions, and log emission growth, respectively. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table IA.4: Equal-Weighted Portfolio Sorting

	L	2	3	4	H	H-L
Panel A: Carbon Intensity						
Scope 1	1.46***	1.61***	1.49***	1.48***	1.21**	-0.25
	(3.34)	(3.71)	(3.08)	(3.19)	(2.33)	(-0.90)
Scope 2	1.38***	1.56***	1.45***	1.52***	1.34**	-0.04
	(3.60)	(3.55)	(3.14)	(3.24)	(2.42)	(-0.13)
Scope 3	1.41***	1.58***	1.47***	1.42***	1.37***	-0.04
	(3.23)	(3.68)	(3.05)	(2.86)	(2.89)	(-0.20)
Panel B: Carbon Emissions						
Scope 1	1.41***	1.63***	1.51***	1.38***	1.31***	-0.09
	(3.08)	(3.65)	(3.18)	(2.86)	(2.89)	(-0.38)
Scope 2	1.28***	1.53***	1.43***	1.54***	1.47***	0.20
	(2.87)	(3.60)	(2.97)	(3.13)	(3.23)	(0.96)
Scope 3	1.31***	1.44***	1.56***	1.51***	1.43***	0.12
	(2.80)	(3.14)	(3.28)	(3.08)	(3.45)	(0.52)
Panel B: Carbon Emission Growth						
Scope 1	1.50***	1.44***	1.42***	1.48***	1.32***	-0.18
	(3.10)	(3.29)	(3.37)	(3.45)	(2.63)	(-1.18)
Scope 2	1.61***	1.41***	1.46***	1.44***	1.24**	-0.36**
	(3.25)	(3.19)	(3.56)	(3.38)	(2.47)	(-2.37)
Scope 3	1.47***	1.49***	1.46***	1.54***	1.19**	-0.28*
	(2.88)	(3.42)	(3.57)	(3.69)	(2.36)	(-1.68)

Notes: This table presents the monthly equal-weighted raw returns of the carbon footprint-sorted portfolios. The sorting variables are carbon intensity, total emissions, and log emission growth, respectively. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table IA.5: Equal-Weighted Portfolio Alphas

	L	2	3	4	H	H-L
Panel A: Scope 1						
α	0.41***	0.20*	0.02	-0.01	-0.21	-0.62**
	(3.37)	(1.78)	(0.16)	(-0.07)	(-1.00)	(-2.15)
MKT	0.95***	1.08***	1.11***	1.11***	1.08***	0.13*
	(31.20)	(38.78)	(35.82)	(38.37)	(19.92)	(1.76)
SMB	0.30***	0.51***	0.74***	0.66***	0.61***	0.31**
	(5.70)	(10.61)	(13.91)	(13.22)	(6.51)	(2.45)
HML	0.59***	-0.12**	-0.07	-0.00	0.21**	-0.38***
	(10.95)	(-2.53)	(-1.36)	(-0.00)	(2.19)	(-2.94)
RMW	-0.26***	-0.19***	-0.08	0.05	0.17	0.43***
	(-3.89)	(-3.20)	(-1.26)	(0.76)	(1.49)	(2.72)
CMA	-0.26***	0.08	0.14	0.01	0.19	0.45**
	(-3.08)	(1.02)	(1.58)	(0.07)	(1.29)	(2.24)
MOM	-0.09**	-0.07**	-0.15***	-0.08**	-0.26***	-0.16*
	(-2.46)	(-1.98)	(-3.87)	(-2.16)	(-3.86)	(-1.84)
R^2	0.94	0.95	0.95	0.95	0.86	0.15
Observations	151	151	151	151	151	151
Panel B: Scope 2						
α	0.41***	0.19**	0.02	0.04	-0.26	-0.67***
	(3.46)	(2.15)	(0.23)	(0.29)	(-1.49)	(-2.80)
MKT	0.83***	1.08***	1.09***	1.10***	1.21***	0.38***
	(27.70)	(48.34)	(43.41)	(35.10)	(27.13)	(6.29)
SMB	0.35***	0.46***	0.60***	0.65***	0.74***	0.39***
	(6.86)	(11.91)	(13.86)	(12.05)	(9.66)	(3.72)
HML	0.46***	0.06	-0.04	-0.06	0.17**	-0.29***
	(8.73)	(1.56)	(-0.84)	(-1.08)	(2.22)	(-2.68)
RMW	-0.11*	-0.17***	-0.13**	-0.06	0.16	0.27**
	(-1.70)	(-3.48)	(-2.45)	(-0.85)	(1.64)	(2.05)
CMA	-0.23***	-0.07	0.09	0.30***	0.06	0.29*
	(-2.78)	(-1.09)	(1.30)	(3.48)	(0.45)	(1.70)
MOM	-0.05	-0.10***	-0.15***	-0.11***	-0.23***	-0.18**
	(-1.34)	(-3.80)	(-4.74)	(-2.77)	(-4.24)	(-2.45)
R^2	0.92	0.97	0.96	0.94	0.92	0.41
Observations	151	151	151	151	151	151

Panel C: Scope 3						
	L	2	3	4	H	H-L
α	0.39***	0.15	0.03	-0.08	-0.08	-0.48**
	(3.13)	(1.23)	(0.21)	(-0.60)	(-0.67)	(-2.49)
MKT	0.92***	1.05***	1.10***	1.14***	1.09***	0.17***
	(29.27)	(34.34)	(32.41)	(32.49)	(34.44)	(3.55)
SMB	0.39***	0.54***	0.67***	0.66***	0.54***	0.16*
	(7.13)	(10.28)	(11.53)	(10.87)	(9.95)	(1.89)
HML	0.56***	-0.09*	-0.07	0.06	0.14**	-0.43***
	(10.17)	(-1.71)	(-1.15)	(0.90)	(2.45)	(-5.03)
RMW	-0.28***	-0.02	-0.17**	0.01	0.15**	0.42***
	(-4.04)	(-0.33)	(-2.35)	(0.14)	(2.15)	(4.05)
CMA	-0.35***	0.13	0.13	0.07	0.18**	0.53***
	(-4.00)	(1.58)	(1.35)	(0.69)	(2.00)	(3.93)
MOM	-0.08**	-0.05	-0.14***	-0.17***	-0.19***	-0.12*
	(-2.03)	(-1.36)	(-3.48)	(-3.95)	(-4.97)	(-1.94)
R^2	0.93	0.93	0.94	0.94	0.94	0.28
Observations	151	151	151	151	151	151

Notes: This table presents the monthly equal-weighted alphas of the carbon intensity-sorted portfolios. The alphas are obtained by regressing the raw returns on the FF6 factors. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table IA.6: Forward-Looking US Regression: Emissions/Log Market Equity

	(1)	(2)	(3)	(4)	(5)	(6)
Scope 1	-0.063**			0.003		
	(-2.34)			(0.07)		
Scope 2		-0.080*			0.052	
		(-1.77)			(0.93)	
Scope 3			-0.060			0.047
			(-1.11)			(0.79)
Beta	0.243	0.318	0.286	0.416	0.378	0.399
	(0.80)	(1.04)	(0.94)	(1.22)	(1.16)	(1.18)
Size	-0.042	-0.020	-0.022	-0.045	-0.044	-0.044
	(-0.55)	(-0.27)	(-0.29)	(-0.48)	(-0.47)	(-0.47)
Book-to-Market	-0.322	-0.320	-0.338	-0.027	-0.054	-0.057
	(-1.53)	(-1.56)	(-1.62)	(-0.15)	(-0.29)	(-0.32)
Gross Profitability	0.192	0.350	0.250	0.555	0.408	0.458
	(0.47)	(0.82)	(0.61)	(1.42)	(1.10)	(1.22)
Operating Profitability	-0.149	-0.142	-0.153	-0.236	-0.265	-0.268
	(-0.55)	(-0.52)	(-0.56)	(-0.83)	(-0.93)	(-0.96)
Asset Growth	-0.362	-0.364	-0.355	-0.502	-0.466	-0.469
	(-1.35)	(-1.30)	(-1.31)	(-1.64)	(-1.53)	(-1.57)
Momentum	-0.091	-0.089	-0.089	0.075	0.059	0.057
	(-0.19)	(-0.18)	(-0.19)	(0.21)	(0.16)	(0.16)
Reversal	-0.928	-0.919	-0.915	-1.974	-1.999	-2.004
	(-0.53)	(-0.53)	(-0.53)	(-1.17)	(-1.18)	(-1.18)
R^2	0.27	0.27	0.27	0.17	0.17	0.17
Observations	207278	207278	207278	207278	207278	207278
Weighted Regression	Y	Y	Y	N	N	
Time FE	Y	Y	Y	Y	Y	Y

Notes: This table reports the results of regressing stock returns on log carbon emissions scaled by year-end market equity. The first three columns present results from the weighted least square regressions, and the last three columns present the ordinary least squares. The regressions control for time fixed effects and the standard errors are double clustered the firm and time level. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.

Table IA.7: International Regressions

	Panel A: Value-Weighted Regressions								
	Carbon Intensity			Emissions			ΔEmissions		
	Scope 1	2	3	1	2	3	1	2	3
Scope 1	-0.05			-0.05			-0.00		
	(-1.13)			(-1.01)			(-0.12)		
Scope 2		-0.04			-0.05			0.03	
		(-1.01)			(-0.89)			(0.92)	
Scope 3			-0.02			-0.01			0.04
			(-0.42)			(-0.23)			(0.81)
Beta	-0.01	0.00	0.00	-0.01	0.00	0.00	0.02	0.02	0.02
	(-0.03)	(0.01)	(0.00)	(-0.02)	(0.01)	(0.01)	(0.09)	(0.09)	(0.08)
Size	-0.08	-0.08	-0.08	-0.06	-0.05	-0.07	-0.08	-0.08	-0.08
	(-1.47)	(-1.39)	(-1.36)	(-1.04)	(-0.96)	(-1.23)	(-1.45)	(-1.46)	(-1.45)
Book-to-Market	0.09	0.08	0.09	0.10	0.10	0.09	0.08	0.08	0.08
	(0.55)	(0.53)	(0.54)	(0.61)	(0.62)	(0.57)	(0.48)	(0.49)	(0.51)
Gross Profitability	1.04***	1.08***	1.06***	1.06***	1.08***	1.05***	1.00***	1.00***	1.00***
	(3.56)	(3.67)	(3.65)	(3.61)	(3.73)	(3.70)	(3.37)	(3.36)	(3.35)
Asset Growth	-0.86***	-0.85***	-0.85***	-0.87***	-0.87***	-0.86***	-0.86***	-0.87***	-0.88***
	(-2.83)	(-2.80)	(-2.80)	(-2.88)	(-2.87)	(-2.82)	(-2.81)	(-2.83)	(-2.87)
Momentum	0.25	0.25	0.25	0.25	0.25	0.25	0.23	0.23	0.23
	(0.77)	(0.76)	(0.76)	(0.78)	(0.77)	(0.76)	(0.71)	(0.71)	(0.72)
Reversal	-1.66	-1.66	-1.66	-1.65	-1.65	-1.66	-1.79	-1.79	-1.79
	(-1.33)	(-1.34)	(-1.34)	(-1.33)	(-1.33)	(-1.33)	(-1.43)	(-1.43)	(-1.43)
R^2	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Observations	694976	694976	694976	694976	694976	694976	642730	642730	642730
	Panel A: Equal-Weighted Regressions								
Scope 1	0.02			0.04			-0.00		
	(0.49)			(0.90)			(-0.16)		
Scope 2		0.03			0.07			0.00	
		(0.79)			(1.36)			(0.03)	
Scope 3			0.01			0.05			-0.09**
			(0.25)			(0.81)			(-2.22)
R^2	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Observations	694976	694976	694976	694976	694976	694976	642730	642730	642730
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: This table reports the results of regressing stock returns on the lagged carbon intensity and lagged controls in the international sample. The regressions control for time fixed effects and the standard errors are double clustered the firm and time level. The t-statistics are reported in the parenthesis below the coefficients. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. The sample period is 2009:06 to 2021:12.