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Carbon Premium in the Tokyo Stock Market

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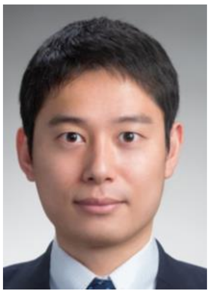
Abstract

This paper presents an empirical analysis of the influence of corporate GHG emissions on the cross-section of Japanese stock returns. We utilized multiple data sources on GHG emissions to investigate this impact. Our findings indicate that there is a negative premium associated with the emissions intensity, which refers to emissions per sales, of the direct emissions. Importantly, this negative premium remains statistically and economically significant even after controlling for other common equity risk factors. Consequently, our results suggest that, unlike the situation in the United States, investors in Japan do not require compensation for their exposure to carbon emission risk.



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1. Introduction

The reduction of greenhouse gases (GHGs), especially carbon dioxide (CO_2), is a critical global issue due to its significant impact on climate change. To address this concern, various international agreements, such as the Paris Agreement, have been established, primarily driven by developed countries. In line with these global efforts, the Japanese government announced in October 2020 its goal to achieve carbon neutrality by 2050. As a result, there is an increasing social expectation for Japanese companies to reduce GHG emissions. In response to this social context, financial institutions, including institutional investors, are increasingly investing in and financing companies and projects that promote decarbonization. In addition to traditional ESG investments, preferential interest rates and funds that focus on decarbonization as green investments are being established. Furthermore, in July 2021, the Bank of Japan announced the introduction of a new financing system to facilitate investment and financing for companies working to combat climate change. While both the public and private sectors in Japan's capital markets have begun to promote various initiatives to reduce GHG emissions, there is still a prevailing normative idea about GHG emission reductions, and it is not fully clear what the actual gains and losses are for investors.

While many empirical studies analyzing the relationship between ESG scores/CSR scores and stock returns, as well as the performance of ESG/SRI funds, have been reported, there are few prior studies focusing on GHG emissions.[1] Since reducing GHG emissions can be considered part of ESG promotion, the empirical studies on ESG investing could be analogous to this case. For instance, similar to ESG activities, reducing GHG emissions could help lower the cost of capital by enhancing the medium- and long-term relationship with stakeholders. Also, there are specific issues related to GHG emissions. For example, investments in facilitating GHG reductions could also encourage more efficient use of energy in production, implying that these investments would bring economic benefits that outweigh the additional costs, even in the short term. From this perspective, it is expected that the stock returns of companies with high emissions would be lower. On the contrary, if an investor requires an additional risk premium from companies with high emissions as compensation for potential "transition

[1] For example, Gillan *et al.* (2021) surveys previous research on the ESG investment performances.

risk," then their stock returns should be higher.

Bolton and Kacperczyk (2021) report that in the U.S. stock market, companies with higher GHG emissions and higher emission growth rates exhibit larger stock returns. Consequently, the market demands these companies to pay an extra risk premium. Furthermore, Bolton and Kacperczyk (2023) also provide a similar result when extending their analysis to 77 countries. Likewise, Walkshäusl (2021) shows that the stocks of companies with higher emissions growth rates tend to outperform, and this tendency strengthened after the Paris Agreement.

On the other hand, Choi *et al.* (2020) conclude from their analysis of 74 international cities that carbon-intensive firms underperform low-emission firms in abnormally warm weather. Cheema-Fox *et al.* (2021) illustrate that a "decarbonization" factor portfolio, which goes long on low carbon intensity sectors, industries, or firms and short on high carbon intensity, yields significant positive excess returns, especially in the U.S. and European stock markets. From another perspective, Ilhan *et al.* (2021) show that more carbon-intensive companies and sectors have larger downside tail risks.

Thus, previous studies have provided inconsistent conclusions about the relationship between stock returns and GHG emissions. Moreover, to the best of the authors' knowledge, there are no empirical studies specifically analyzing this relationship in the Japanese stock market.[2] As the importance of risk factors in equity markets varies across countries, conducting country-specific empirical analyses of the equity risk premium associated with GHG emissions would be significant for both academic researchers and financial practitioners.

In this paper, our focus is on Japan, and we aim to uncover the connection between stock returns and GHG emissions in the Tokyo stock market. In particular, we will conduct a comparative analysis using multiple sources and types of GHG emission data to obtain robust evidence about the relationship.

This paper is organized as follows: Section 2 describes the data, Sections 3 to 6 present the methodologies and results of the individual analyses, and Section 7 provides our conclusion.

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[2] Although not directly examining stock returns, Matsumura *et al.* (2014) analyzed the relationship between corporate CO_2 emissions and stock market capitalization in the S&P 500 Index and reported a negative relationship between the two variables. Similarly, Aruga, Goshima, and Chiba (2021) analyzed Japanese listed companies and found that those with lower CO_2 emissions tend to have lower costs of equity.

2. GHG emissions data

We used two sources of firm-level GHG emissions data: CDP and Corporate Disclosure, both obtained from Bloomberg. It is important to note that all GHG emission values have been converted to CO_2 equivalents.[3] CDP, the first data source, is an international initiative that operates as a UK-based NGO. It runs a global disclosure system for various entities, including investors, companies, and public sectors, that assists them in managing their environmental impacts. CDP conducts surveys and evaluations on behalf of institutional investors to assess individual companies' efforts to address climate change and the status of their GHG emission accounting and management practices (Ministry of Economy, Trade and Industry (2018, 2019)). Through its annual corporate survey, companies respond to the CDP Climate Change Questionnaire, and the GHG emissions reported by CDP are therefore based on data provided directly by the companies themselves. In the case of Japanese companies, the questionnaire is mainly sent to 500 companies selected from those in the FTSE Japan Index, and 375 companies responded in 2020 (CDP Worldwide-Japan (2021)). The CDP-reported GHG emission data adhere to the GHG protocol and are separately aggregated into three categories: SCOPE 1, SCOPE 2, and SCOPE 3. SCOPE 1 represents direct GHG emissions that are owned and controlled by companies, including emissions from facilities managed by companies and emissions from their own vehicles. SCOPE 2 and SCOPE 3 refer to indirect GHG emissions resulting from business activities. SCOPE 2 is limited to indirect emissions from the company's use of electricity, heat, cooling, and steam supplied by others, whereas SCOPE 3 covers other indirect emissions related to the corporate value chain, such as purchase of goods and services, use of products, transportation, and distribution (WRI and WBCSD (2004)). SCOPE 3 is further subdivided into 15 categories based on the type of activity involved (WRI and WBCSD (2013)).

The second data source is Corporate Disclosure, which includes information about GHG and/or CO_2 emissions voluntarily disclosed by companies in their annual reports, CSR reports, and other disclosures. Although this dataset covers the same three categories of GHG emissions as the CDP data,

[3] GHGs include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.

it should be noted that it may not necessarily be in accordance with the CDP standards.[4] We also include CO_2 emission data from Corporate Disclosure for our analyses. Similar to GHG data, CO_2 data is aggregated into three categories: direct emissions (DIRECT), indirect emissions (INDIRECT), and total emissions (TOTAL). Roughly speaking, DIRECT corresponds to SCOPE 1, while INDIRECT corresponds to SCOPE 2 and 3. TOTAL represents the total amount of CO_2 emitted by each company, including both DIRECT and INDIRECT emissions.

In the following analyses, SCOPE 1, SCOPE 2, and SCOPE 3 (DIRECT, INDIRECT, and TOTAL) are considered separately. Additionally, following Bolton and Kacperczyk (2021), we define three types of GHG emission indicators for each category, as shown in Table 1: the emission level (AMOUNT), the year-over-year change in emissions (the emission growth rate, GROWTH_RATE), and the emissions per unit of sales (the emission intensity, INTENSITY).[5] The issues below are relevant to SCOPE 2 and SCOPE 3 of CDP data. First, we consider the new SCOPE 2 guidelines introduced in the GHG Protocol in 2015. The new guidance provides two calculation methods for SCOPE 2 emissions: the location-based method and the market-based method, and states that companies are encouraged to disclose emissions measured under both methods[6] (WRI and WBCSD (2015)). In our analyses, we only used the location-based emissions for SCOPE 2 after the introduction of the new guidance. Also, we assume that GROWTH_RATE for SCOPE 2 is missing immediately after the introduction of the new guidance in order to ensure data consistency. Next, our SCOPE 3 emissions are limited to the sum of two subcategories: purchased goods and services and use of sold products. These categories are known to account for the majority of total emissions in SCOPE 3 (CDP Worldwide (2016)).

Table 2 presents the descriptive statistics for the GHG emissions data used in the following analyses. All data is in metric tons of CO_2 equivalent and covers the period 2009–2020. Table 3 also

[4] For SCOPE 3 in particular, there may be variations between firms and between years, as only aggregate values are obtained.

[5] In the following analysis, we confirm that the same results would be obtained if we used an indicator for emission intensity divided by total assets instead of sales.

[6] The location-based method calculates emissions using average emission factors for a specific geographical area and time frame. On the other hand, the market-based method is based on the electricity contracts of the reporting company, taking into account each company's energy choices for emissions calculations, such as renewable and low-carbon electricity options (WRI and WBCSD (2015)).

provides the number of companies included in each year. CDP records show a relatively larger number of firms, but TOTAL of CO_2-Corporate Disclosure has the largest number of companies throughout the period.

Since these GHG emissions data are reported annually, in subsequent analyses we convert them from an annual basis to a monthly basis by interpolating with the most recent annual records.[7] Our GHG datasets are updated annually, using the last day of the CDP reporting year as the updated date for CDP and the last day of each company's fiscal year as the updated date for Corporate Disclosure. For months that do not coincide with an updated date, the most recent historical data is filled. If data have not been updated for 12 months or more, up to 11 months of data are interpolated with the most recent historical data, but missing values are assigned for 12 months and beyond.

3. GHG Emissions and Stock Returns

We begin with conducting a pooled regression (1) to examine the cross-sectional relationship between GHG emissions and stock returns, with reference to Bolton and Kacperczyk (2021).

$$RET_{i,t} = b_0 + b_1 GHG\_Emissions_{i,t} + b_2 Control_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

where RET is the monthly total return of an individual stock, $GHG\_Emissions$ is the GHG emission indicators defined in section 2, $Control$ is the control variables which represent the characteristics of the individual firm, ε is the error terms. Each firm and timestamp is denoted by i and t, respectively. Our control variables are aligned with those in Bolton and Kacperczyk (2021), and their definitions are described in Table 4.[8] We deal with outliers by winsorizing all variables at the 0.5% level on both sides in order to minimize their impact on estimation. Additionally, for RET, any records exceeding 100% are treated as missing values. When estimating (1), we consider industry, year, and month fixed effects. We adopt the TSE large industrial classification (10 sectors) for industry fixed effect.[9] Our key interest

[7] We have also performed the analysis on an annual basis in Section 3 and subsequent sections, and have verified that the same results can be obtained.
[8] See the online appendix for the basic statistics of each variable.
[9] We confirmed that the same results can be obtained when using the Global Industry Classification Standard (GICS).

lies in b_1, the regression coefficient for an emission indicator in (1): if b_1 is significantly positive, we can interpret it as an indication of a positive premium associated with the GHG emission indicator. Conversely, if the coefficient is negative, it suggests the presence of a negative premium.

Table 5 shows the results of the pooled OLS estimation for equation (1). The figures in parentheses represent cluster-robust standard errors at the firm and year. Regarding the emission level, the coefficients do not appear to be significant for any emission category of GHG-CDP and GHG-Corporate Disclosure. However, they are significantly negative for all emission categories of CO_2-Corporate Disclosure. As for the emission growth rate, none of the emission indicators, except SCOPE 2 of GHG-Corporate Disclosure, show significant coefficients, implying a lack of observable premiums in general. With respect to the emission intensity, the coefficients for direct emissions, SCOPE 1 of GHG-CDP, SCOPE 1 of GHG-Corporate Disclosure, and DIRECT of CO_2-Corporate Disclosure, are consistently negative across all data sources, indicating the presence of a negative premium. On the other hand, SCOPE 2 of GHG-Corporate Disclosure and INDIRECT of CO_2-Corporate Disclosure exhibit significantly positive coefficients. TOTAL of CO_2-Corporate Disclosure demonstrates a significantly negative coefficient, although its value appears smaller compared to that of DIRECT of CO_2-Corporate Disclosure. This difference can be explained by the fact that TOTAL is the sum of DIRECT and INDIRECT, which may offset the premium.

These findings differ significantly from the empirical evidence in the U.S. stock market provided Bolton and Kacperczyk (2021), which suggests that there are positive carbon premiums associated with the emission level and emission growth rate, but no premium for emission intensity[10]. Also, our research shows that carbon premiums are not consistent across different emission categories, which contrasts with the findings of Bolton and Kacperczyk (2021). These discrepancies imply that there may be a different pricing mechanism for carbon emission risk factors in the stock market between the United States and Japan.

[10] Furthermore, Bolton and Kacperczyk (2023) report that, similar to the U.S. stock market, the Chinese stock market also exhibits a positive premium in the emission level and the emission growth rate.

4. Carbon Premium and Risk Factor

We next examine whether the carbon premiums observed in the previous section can persist after controlling for other well-known equity risk factors using the Fama-MacBeth regression with (2)[11]

$$b_{1,t} = c_0 + cF_t + \varepsilon_t \tag{2}$$

where b_1 is a series of carbon premiums estimated on a monthly basis through a cross-sectional regression with (1), and F represents equity risk factor returns. We employ seven common equity factor returns for F, namely the market factor (MKT-RF), the size factor (SMB), the value factor (HML), the momentum factor (MOM), the profitability factor (RWM), the investment factor (CMA), and the liquidity factor (LIQ) (Jegadeesh and Titman (1993), Pastor and Stambaugh (2003), Fama and French (2015))[12]. All of these factors are specifically defined for the Japanese stock market and are provided by Financial Data Solutions Inc. in Japan. We focus on c_0, which is the intercept of (2). If c_0 exhibits a significantly positive or negative value, it means that there still exists a carbon premium even after considering other equity risk factors.

Table 6 shows the estimation results of (2). The values in parentheses represent Newey-West standard errors with a lag of 12. For the emissions level, while INDIRECT of CO_2-Corporate Disclosure and TOTAL of CO_2-Corporate Disclosure show significantly negative intercepts, none of the other emissions do. Thus, as in the case of the previous pooled regression, we do not obtain consistent evidence across the data sources regarding the premium on the emission level. This inconsistency may be due to the difference in sampled firms between the data sources, hence indicating the need for more detailed analysis in the future. In the case of the emissions growth rate, as in the previous section, no premium is uniformly observed. Regarding the emission intensity, the intercepts of any of the direct emissions (SCOPE 1 of GHG-CDP, SCOPE 1 of GHG-Corporate Disclosure, and DIRECT of CO_2-Corporate Disclosure) are significantly negative regardless of the data sources, which is line with the

[11] Specifically, in the first step, the sample is divided by month, and then a cross-sectional regression based on (1) is conducted to calculate time series data for b_1. In the second step, the monthly estimates of b_1 are used to perform a time-series regression based on (2).

[12] All equity factor returns include stocks from the financial sector in their calculation universe.

previous section. In contrast, the significant positive premium observed in the previous section is lost for INDIRECT for CO_2-Corporate Disclosure, while it remains for SCOPE 2 of GHG-Corporate Disclosure. Additionally, TOTAL of CO_2-Corporate Disclosure still maintains a significant intercept, but its value appears smaller than that of DIRECT of CO_2-Corporate Disclosure.

These results indicate that a negative premium still exists in the Tokyo stock market for the emission intensity of the direct emissions, even after accounting for other equity risk factors. Although there are other emission indicators for which premiums could be observed, the results are not consistent across the data sources or are not in accordance with the results in Section 3, and therefore may be less reliable.

5. Long/Short strategy based on GHG emission indicators

In this section, we validate the negative carbon premium discovered in previous analyses for the emission intensity of the direct emissions by using "carbon-emission" factor portfolios. Here, we construct long-short portfolios based on the emission indicators and examine their risk-adjusted returns. To control for the industry effect, we only include firms that belong to the manufacturing sector as defined in the TSE large industrial classification, which has the largest number of sampled firms in our datasets. We also only investigate cases with SCOPE 1 of GHG-CDP and TOTAL of CO_2-Corporate Disclosure, both of which ensure a sufficient sample size for simulating a long-short portfolio over a long timeframe[13].

We compute the carbon-emission factor portfolios using the following procedure. First, we sort the companies in descending order for each emission intensity and divide them into the top 50% group and the bottom 50% group. We then create separate portfolios for the two groups, referring to the former as the top portfolio and the latter as the bottom portfolio. For the top portfolio, we re-rank the firms in ascending order of their emission intensity and calculate the portfolio weight in a rank-weighted manner.

[13] While a more segmented industry classification is desirable in some respects, it is important to consider the number of firms within each industry classification. Having a sufficient number of firms is crucial to effectively mitigate the specific risks associated with individual companies. Therefore, this paper uses the TSE industry classification (large category) to control for both the industry effect and the specific risk of individual companies.

The bottom portfolio is determined in a similar way, but with a descending order of the emission intensity. As a result, the top portfolio holds a larger proportion of firms with higher emission intensities, whereas the bottom portfolio consists of more firms with lower emission intensities. The final portfolio is composed by shorting 100% of the top portfolio and longing 100% of the bottom portfolio. The net holding of the entire portfolio is therefore 0% (the face value of the long side is equal to that of the short side). We repeat this procedure monthly to rebalance the portfolio. Given the time lag in data availability, we use emission indicators from one month to six months prior to the rebalance date to construct the portfolio.

Finally, we conduct a time-series regression on the return series of the above portfolio as shown in (3).

$$R_t = \alpha + \beta F_t + \varepsilon_t \tag{3}$$

where R is the portfolio return, F is the same factor returns as in Section 4. A significantly positive α indicates that the risk-adjusted return is positive and cannot explained by the common equity risk factors. Table 7 displays the estimated α with different time lags for the emission indicator. The figures in parentheses represent the Newey-West standard errors with a lag of 12. Both portfolios based on SCOPE 1 of GHG-CDP and TOTAL of CO_2-Corporate Disclosure show significant positive risk-adjusted returns. Furthermore, these returns remain significant even with longer data reference lags of up to six months. This result suggests that there is a negative premium on the emission intensity of the direct emissions, which supports the findings reported in the previous section.[14]

[14] Although not listed in this paper, there are cases where α was found to be significantly positive for emission indicators other than the emission intensity. This may be because some of the rank correlations among the emission indicators are high, resulting in long/short portfolios consisting of similar stocks.

6. Impact of the Paris Agreement

Finally, we discuss the changes in the risk premium on GHG emissions over our sample period. The Paris Agreement, which was adopted in 2015, raised global awareness of the climate change risks and therefore could have had an impact on the risk premium. In order to analyze the impact of the Paris Agreement, we conduct a regression analysis by adding a cross term representing the period after the agreement to (1), as shown in (4).

$$RET_{i,t} = d_0 + d_1 GHG\_Emissions_{i,t} + d_2\left(Dummy\_PostCOP21_t \times GHG\_Emissions_{i,t}\right) + d_3 Control_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

where $Dummy\_PostCOP21$ is a dummy variable that takes the value of 1 if the date t is after the adoption of the Paris Agreement, and 0 otherwise. If the coefficient d_2 is significant, it indicates that the risk premium on GHG emissions would have changed before and after the Paris Agreement. The following analyses present the cases with the emission intensities of the direct emissions where risk premiums are observed in the previous results.

Table 8 summarizes the estimated values of d_1 and d_2 in (4). d_1 still shows a significantly negative value regardless of the data sources, which is similar to the previous sections. With respect to d_2, it appears to be significantly positive in some of the emission indicators, specifically SCOPE 1 of GHG-Corporate Disclosure and DIRECT of CO_2-Corporate Disclosure. This result may reflect changes in the risk premium that result from the shift in investor behavior due to the adoption of the Paris Agreement. For instance, the Paris Agreement might prompt investors to be more concerned about the transition risks of individual companies, thereby diminishing the negative premium. Further analysis is necessary to fully interpret this result in the future.

7. Conclusion

This paper examines the relationship between stock returns and corporate greenhouse gas emissions in the Tokyo stock market. We employed multiple data sources and GHG emission indicators to assess this relationship comprehensively. Our findings reveal a significant negative premium associated with the emission intensity of the direct carbon emissions in the Tokyo stock market, and it remains even after controlling for common equity risk factors. These results are in contrast to prior research conducted on the U.S. stock market, which implies that the risk premium associated with GHG emissions is priced differently between these two stock markets. Compared to U.S. companies, Japanese companies may be perceived as having lower transition risk by the financial market due to their generally lower GHG emissions and the policies introduced by the Japanese government to encourage GHG emission reductions, such as the "Tax for Climate Change Mitigation" which came into force in 2012.

It is important to note that different conclusions about the carbon risk premium may be reached depending on the data sources used for analysis. Since our analysis is only based on the available GHG emission data, there may be a selection bias related to the sample companies that we observed.

Our findings provide valuable insights for decision-making related to decarbonization in Japan, including policymaking and investment strategies. In particular, the contrast between Japan and the United States highlights the importance of utilizing local data when addressing the issue of corporate GHG emissions. Furthermore, our study emphasizes the importance of carefully selecting GHG emission data.

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Table 1: GHG Emission Indicators

Variable	Definition
AMOUNT	Level of GHG emissions (mtCO2e, natural log scale)
GROWTH_RATE	Year-over-year change in GHG emissions
INTENSITY	GHG emissions per unit of sales revenue (JPY)

Table 2: Descriptive Statistics for GHG Emissions Data (in metric tons of CO_2 equivalent)

Source	Category		Mean	Min	P25	P50	P75	Max	Std
CDP	GHG	SCOPE 1	1,965,686	0	15,000	101,000	408,000	63,800,000	7,524,551
		SCOPE 2	521,729	0	52,000	188,000	585,000	5,788,000	895,680
		SCOPE 3	19,799,234	0	714,000	2,728,000	12,160,000	385,600,000	51,649,506
CORPORATE DISCLOSURE	GHG	SCOPE 1	1,575,339	0	16,558	133,440	377,426	82,008,000	6,834,408
		SCOPE 2	656,377	50	59,900	205,392	700,000	7,000,000	1,107,050
		SCOPE 3	14,080,229	746	89,394	1,100,330	5,960,000	357,490,000	45,245,441
	CO2	DIRECT	1,236,945	0	5,033	27,882	147,281	82,008,000	7,435,127
		INDIRECT	422,568	664	15,891	88,692	311,000	7,500,000	995,471
		TOTAL	1,588,443	442	24,436	89,111	398,900	61,405,000	6,922,357

Table 3: Number of Companies Per Year in Our Datasets

Source	Category		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CDP	GHG	SCOPE 1	193	205	213	222	230	253	263	293	318	356	389	325
		SCOPE 2	192	205	208	218	228	251	249	236	261	293	326	273
		SCOPE 3							119	146	193	209	188	160
CORPORATE DISCLOSURE	GHG	SCOPE 1					51	64	79	101	124	134	151	139
		SCOPE 2					51	64	79	100	123	133	149	138
		SCOPE 3					103	141	162	188	218	237	254	248
	CO2	DIRECT	63	63	60	72	71	91	107	136	159	176	190	177
		INDIRECT	58	62	60	72	70	89	103	135	157	172	184	170
		TOTAL	523	530	541	546	546	546	537	553	547	541	534	491

Table 4: Definition of Variables for Corporate Characteristics

Variable	Definition
RET	Monthly total return of a single stock.
LOGSIZE	Market capitalization (natural log scale).
B/M	Book-to-Market ratio, book value of equity divided by market capitalization.
ROE	Return on Equity, net income divided by average shareholder's equity for the year.
LEVERAGE	Book leverage, sum of current and non-current liabilities divided by total assets.
INVESTMENT/ASSET	Capital expenditures divided by total assets.
HHI	Herfindahl index based on sales ratios by business segment.
LOGPPE	Net amount of property, plant, and equipment (natural log scale).
MOM	Past one-year total return of a single stock.
BETA	Beta to market return over the past one year.
VOL	Annualized standard deviation of monthly stock returns over the past 12 months.
SALESGR	Annual change in revenue divided by last month's market capitalization.
EPSGR	Annual change in earnings per share divided by share price.

Table 5: Pooled OLS - GHG Emissions and Stock Returns

(Note: ***, **, and * indicate that the regression coefficients are significant at 1%, 5%, and 10% two-tailed probability, respectively. Same as Tables 6–8 below.)

(a) CDP: GHG

Variables	SCOPE 1	SCOPE 2	SCOPE 3	SCOPE 1	SCOPE 2	SCOPE 3	SCOPE 1	SCOPE 2	SCOPE 3
AMOUNT	-0.024	-0.017	0.034						
	(0.020)	(0.045)	(0.027)						
GROWTH_RATE				0.114	-0.362	0.049			
				(0.275)	(0.308)	(0.317)			
INTENSITY							-0.039**	0.073	0.005
							(0.016)	(0.129)	(0.016)
LOGSIZE	0.438**	0.466**	0.619	0.432*	0.471**	0.669*	0.401*	0.460**	0.693
	(0.214)	(0.227)	(0.418)	(0.227)	(0.199)	(0.403)	(0.214)	(0.228)	(0.438)
B/M	0.833	1.001*	1.092**	0.760*	0.607	0.276	0.881	1.052*	1.230***
	(0.518)	(0.528)	(0.505)	(0.430)	(0.438)	(0.700)	(0.540)	(0.561)	(0.398)
LEVERAGE	0.236	0.272	0.902	-0.213	0.038	0.182	0.400	0.357	0.639
	(0.423)	(0.513)	(0.809)	(0.550)	(0.579)	(0.637)	(0.423)	(0.518)	(0.830)
MOM	-2.697**	-2.854***	-0.914	-2.689**	-2.728**	-1.488	-2.734***	-2.898***	-1.055
	(1.048)	(0.980)	(1.962)	(1.134)	(1.064)	(2.099)	(1.018)	(0.944)	(1.928)
INVESTMENT/ASSET	-1.463	-1.779	-5.250	-4.818	-3.215	-8.124	-2.550	-2.185	-4.270
	(3.738)	(3.990)	(7.096)	(4.442)	(5.532)	(8.738)	(3.619)	(4.465)	(7.800)
ROE	2.802	3.299*	1.883	2.767*	3.014	-3.233	3.139	3.413*	2.131
	(1.731)	(1.782)	(2.594)	(1.467)	(2.002)	(3.308)	(1.915)	(1.942)	(2.401)
HHI	-0.489	-0.450	-0.767	-0.642	-0.515	-1.132	-0.461	-0.396	-0.706
	(0.403)	(0.449)	(0.515)	(0.412)	(0.462)	(0.749)	(0.400)	(0.438)	(0.673)
LOGPPE	-0.360**	-0.402**	-0.544**	-0.433***	-0.435***	-0.389*	-0.358***	-0.429**	-0.584**
	(0.140)	(0.167)	(0.275)	(0.154)	(0.154)	(0.225)	(0.138)	(0.171)	(0.291)
BETA	-1.456	-1.448	-1.683	-1.512	-1.227	-1.728	-1.456	-1.453	-1.668
	(1.526)	(1.597)	(2.220)	(1.543)	(1.651)	(1.919)	(1.508)	(1.600)	(2.325)
VOL	11.285	11.356	13.892	11.896	9.854	17.150	11.637	11.597	14.071
	(8.007)	(8.285)	(12.653)	(8.511)	(9.728)	(13.897)	(7.952)	(8.290)	(13.044)
SALESGR	-0.815**	-0.783**	-0.402	-0.571	-0.455	-1.524***	-0.803**	-0.738*	-0.345
	(0.375)	(0.398)	(0.383)	(0.467)	(0.570)	(0.392)	(0.397)	(0.413)	(0.353)
EPSGR	-0.201	-0.432	0.369	-0.230	0.324	-0.909	-0.310	-0.354	0.868
	(1.856)	(1.890)	(2.499)	(1.260)	(1.646)	(3.534)	(1.916)	(2.004)	(2.146)
Year/Month Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	33,300	29,214	9,018	24,720	19,298	5,818	31,981	28,104	8,566
Adjusted R-squared	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01

(b) Corporate Disclosure: GHG

Variables	SCOPE 1	SCOPE 2	SCOPE 3	SCOPE 1	SCOPE 2	SCOPE 3	SCOPE 1	SCOPE 2	SCOPE 3
AMOUNT	-0.037	-0.068	-0.019						
	(0.095)	(0.071)	(0.028)						
GROWTH_RATE				-0.028	-2.181***	-0.173			
				(0.430)	(0.298)	(0.231)			
INTENSITY							-0.056**	0.208**	-0.001
							(0.028)	(0.098)	(0.008)
LOGSIZE	0.496	0.534	0.535*	0.525	0.521	0.493	0.452	0.563*	0.518*
	(0.351)	(0.348)	(0.283)	(0.345)	(0.360)	(0.357)	(0.358)	(0.328)	(0.282)
B/M	0.623	0.658*	0.724**	0.631*	0.657*	0.659*	0.625*	0.639*	0.735**
	(0.379)	(0.382)	(0.362)	(0.356)	(0.351)	(0.362)	(0.378)	(0.369)	(0.354)
LEVERAGE	-0.613	-0.724	-0.322	-0.136	-0.105	-0.524	-0.531	-0.697	-0.386
	(0.692)	(0.658)	(0.530)	(0.555)	(0.641)	(0.467)	(0.702)	(0.656)	(0.556)
MOM	-2.758**	-2.769**	-1.704	-2.267*	-2.317*	-1.483	-2.728**	-2.869**	-1.689
	(1.238)	(1.252)	(1.379)	(1.183)	(1.213)	(1.676)	(1.239)	(1.238)	(1.383)
INVESTMENT_ASSET	0.540	0.254	2.292	-1.716	-1.881	3.329	0.207	-1.146	2.519
	(7.599)	(8.431)	(5.579)	(8.391)	(8.733)	(6.049)	(8.370)	(8.718)	(5.663)
ROE	1.240	1.339	1.114	1.966	2.440	2.124	1.297	1.125	1.145
	(1.550)	(1.558)	(1.081)	(1.863)	(1.878)	(1.365)	(1.557)	(1.538)	(1.047)
HHI	0.011	-0.094	-0.923	0.396	0.327	-1.016*	0.055	0.045	-0.940
	(0.474)	(0.452)	(0.636)	(0.476)	(0.488)	(0.616)	(0.469)	(0.483)	(0.668)
LOGPPE	-0.238	-0.253	-0.371**	-0.269	-0.269	-0.308	-0.237	-0.358*	-0.380**
	(0.254)	(0.190)	(0.182)	(0.223)	(0.234)	(0.249)	(0.212)	(0.199)	(0.186)
BETA	-0.440	-0.394	-1.965	-0.209	-0.102	-2.251	-0.436	-0.422	-2.006
	(1.885)	(1.832)	(1.460)	(2.135)	(2.125)	(1.506)	(1.844)	(1.807)	(1.475)
VOL	11.837	12.056	13.454	14.985	14.960	15.043*	11.889	11.665	13.592
	(10.646)	(10.394)	(8.772)	(11.151)	(11.138)	(9.042)	(10.365)	(10.452)	(8.835)
SALESGR	-0.174	-0.169	-0.840*	-0.178	-0.279	-1.140***	-0.247	-0.252	-0.840**
	(0.468)	(0.464)	(0.431)	(0.545)	(0.646)	(0.406)	(0.453)	(0.472)	(0.427)
EPSGR	1.337	1.267	0.250	0.920	0.954	-0.009	1.384	1.363	0.242
	(1.651)	(1.602)	(0.822)	(2.028)	(1.950)	(0.474)	(1.762)	(1.628)	(0.820)
Year/Month Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,090	8,042	15,019	6,035	6,119	11,204	8,090	8,042	14,971
Adjusted R-squared	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01

(c) Corporate Disclosure: CO_2

Variables	DIRECT	INDIRECT	TOTAL	DIRECT	INDIRECT	TOTAL	DIRECT	INDIRECT	TOTAL
AMOUNT	-0.123**	-0.147**	-0.161**						
	(0.055)	(0.065)	(0.066)						
GROWTH_RATE				-0.302	-0.463	-0.496			
				(0.450)	(0.699)	(0.410)			
INTENSITY							-0.152***	0.015***	-0.030**
							(0.043)	(0.000)	(0.015)
LOGSIZE	0.274	0.197	0.367**	0.303	0.190	0.260*	0.273	0.181	0.360**
	(0.226)	(0.233)	(0.170)	(0.248)	(0.243)	(0.142)	(0.235)	(0.233)	(0.169)
B/M	0.965**	0.760**	0.846***	0.786**	0.597**	0.529***	0.980**	0.747*	0.836***
	(0.408)	(0.388)	(0.296)	(0.308)	(0.283)	(0.137)	(0.412)	(0.396)	(0.297)
LEVERAGE	-0.230	-0.365	0.381	-0.448	-0.645	-0.059	-0.075	-0.292	0.379
	(0.605)	(0.642)	(0.440)	(0.591)	(0.540)	(0.329)	(0.604)	(0.641)	(0.439)
MOM	-2.593**	-2.315*	-2.679***	-2.090	-1.732	-2.044**	-2.592**	-2.283*	-2.667***
	(1.296)	(1.334)	(0.994)	(1.383)	(1.376)	(0.954)	(1.300)	(1.338)	(0.990)
INVESTMENT_ASSET	7.321	6.072	3.610	7.500	4.529	-0.335	7.690	5.318	2.791
	(4.859)	(3.961)	(4.360)	(5.799)	(5.262)	(3.824)	(4.918)	(4.142)	(4.301)
ROE	4.223***	5.612***	2.260*	4.276**	5.179**	1.234	4.388***	5.743***	2.330*
	(1.494)	(1.782)	(1.241)	(1.715)	(2.063)	(0.975)	(1.558)	(1.782)	(1.266)
HHI	-0.510	-0.755*	-0.333	-0.596	-0.820*	-0.245	-0.499	-0.715*	-0.282
	(0.422)	(0.427)	(0.243)	(0.403)	(0.426)	(0.239)	(0.410)	(0.423)	(0.237)
LOGPPE	0.015	0.045	-0.096	-0.144	-0.108	-0.186*	-0.101	-0.095	-0.256*
	(0.183)	(0.185)	(0.138)	(0.219)	(0.199)	(0.105)	(0.186)	(0.180)	(0.139)
BETA	-1.378	-1.153	-0.656	-1.188	-0.797	-0.600	-1.438	-1.188	-0.654
	(1.268)	(1.214)	(0.845)	(1.220)	(1.202)	(0.865)	(1.281)	(1.225)	(0.846)
VOL	11.638*	9.526	6.821*	11.582	8.342	5.520	11.823*	9.531	6.787*
	(6.517)	(6.506)	(4.030)	(7.209)	(7.140)	(4.321)	(6.620)	(6.521)	(4.031)
SALESGR	-0.543***	-0.394	-0.460**	-0.622**	-0.446	-0.426*	-0.554***	-0.404*	-0.457**
	(0.186)	(0.240)	(0.179)	(0.314)	(0.331)	(0.247)	(0.191)	(0.242)	(0.179)
EPSGR	-1.472	-3.208	-0.927	-2.267	-4.592	-0.923	-1.627	-3.240	-0.967
	(1.172)	(2.206)	(1.233)	(1.697)	(3.240)	(1.612)	(1.171)	(2.200)	(1.245)
Year/Month Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,046	13,715	73,107	11,135	10,982	64,341	14,043	13,712	73,092
Adjusted R-squared	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01

Table 6: Fama-Macbeth Regression - Carbon Premium and Equity Risk Factors

(a) Emission Level

	CDP: GHG			CORPORATE DISCLOSURE: GHG			CORPORATE DISCLOSURE: CO2		
	SCOPE_1	SCOPE_2	SCOPE_3	SCOPE_1	SCOPE_2	SCOPE_3	DIRECT	INDIRECT	TOTAL
constant	-0.020	0.001	0.100*	-0.013	0.157*	-0.010	-0.062	-0.127*	-0.089**
	(0.021)	(0.029)	(0.057)	(0.055)	(0.083)	(0.019)	(0.042)	(0.074)	(0.039)
MKT-RF	-0.003	-0.013	0.010**	0.020	-0.001	-0.002	0.004	0.030	-0.010
	(0.004)	(0.010)	(0.005)	(0.012)	(0.028)	(0.006)	(0.009)	(0.022)	(0.008)
HML	0.005	0.066**	-0.009	-0.029	0.040	0.031***	0.027	0.021	0.088***
	(0.011)	(0.030)	(0.016)	(0.028)	(0.044)	(0.011)	(0.021)	(0.044)	(0.016)
SMB	-0.009	-0.014	-0.018	-0.030	0.002	0.001	-0.018	-0.095***	-0.033**
	(0.007)	(0.017)	(0.016)	(0.019)	(0.034)	(0.010)	(0.020)	(0.032)	(0.013)
RMW	-0.009	0.024	-0.009	-0.125**	0.028	0.009	0.039	0.029	0.013
	(0.013)	(0.020)	(0.031)	(0.050)	(0.077)	(0.023)	(0.031)	(0.081)	(0.026)
CMA	0.010	0.005	-0.034	-0.043	0.105	-0.021	0.023	0.062	0.001
	(0.014)	(0.031)	(0.025)	(0.040)	(0.071)	(0.015)	(0.034)	(0.076)	(0.025)
MOM	0.000	0.008	0.009	0.038	-0.035	0.012	0.000	-0.034	0.002
	(0.004)	(0.010)	(0.010)	(0.026)	(0.028)	(0.008)	(0.016)	(0.025)	(0.010)
LIQ	-0.008	0.021	-0.011	-0.019	0.071**	-0.007	-0.021	-0.068**	-0.038***
	(0.007)	(0.013)	(0.014)	(0.016)	(0.032)	(0.007)	(0.014)	(0.026)	(0.014)
Observations	144	144	60	84	84	84	144	144	144
Adjusted R-squared	0.01	0.08	-0.03	0.01	0.05	-0.02	-0.03	0.05	0.25

(b) Emission Growth Rate

	CDP: GHG			CORPORATE DISCLOSURE: GHG			CORPORATE DISCLOSURE: CO2		
	SCOPE_1	SCOPE_2	SCOPE_3	SCOPE_1	SCOPE_2	SCOPE_3	DIRECT	INDIRECT	TOTAL
constant	-0.231	0.111	0.004	-0.154	-0.624	-0.178	-0.387	-0.011	-0.088
	(0.189)	(0.156)	(0.276)	(0.879)	(0.900)	(0.164)	(0.350)	(0.577)	(0.170)
MKT-RF	0.070	-0.060	-0.044	0.124	0.461***	0.031	-0.082	-0.170	-0.094**
	(0.066)	(0.037)	(0.070)	(0.167)	(0.163)	(0.038)	(0.112)	(0.182)	(0.046)
HML	0.079	0.034	-0.413	-0.834**	0.719**	-0.148	0.158	0.101	0.035
	(0.121)	(0.090)	(0.310)	(0.364)	(0.296)	(0.158)	(0.238)	(0.340)	(0.101)
SMB	0.064	0.026	-0.116	-0.080	0.230	0.095	-0.168	0.081	0.048
	(0.087)	(0.088)	(0.104)	(0.282)	(0.366)	(0.098)	(0.168)	(0.247)	(0.081)
RMW	0.000	-0.047	-0.187	-1.346**	1.223*	-0.116	-0.323	-0.339	-0.255
	(0.176)	(0.130)	(0.209)	(0.656)	(0.632)	(0.263)	(0.370)	(0.538)	(0.156)
CMA	-0.024	-0.006	0.286	-0.441	0.239	0.036	-0.760**	0.282	-0.218
	(0.146)	(0.152)	(0.202)	(0.532)	(0.611)	(0.164)	(0.327)	(0.380)	(0.137)
MOM	0.102	-0.005	-0.164	-0.060	0.626**	-0.062	0.017	0.386*	0.002
	(0.108)	(0.057)	(0.244)	(0.409)	(0.252)	(0.073)	(0.174)	(0.223)	(0.086)
LIQ	-0.184***	-0.108*	0.248	-0.122	-1.004**	0.163	-0.226*	-0.016	0.030
	(0.065)	(0.062)	(0.154)	(0.192)	(0.383)	(0.137)	(0.122)	(0.187)	(0.074)
Observations	132	120	48	72	72	72	132	132	132
Adjusted R-squared	0.03	-0.01	0.00	-0.03	0.02	-0.04	0.01	0.00	-0.01

(c) Emission Intensity

	CDP: GHG			CORPORATE DISCLOSURE: GHG			CORPORATE DISCLOSURE: CO2		
	SCOPE_1	SCOPE_2	SCOPE_3	SCOPE_1	SCOPE_2	SCOPE_3	DIRECT	INDIRECT	TOTAL
constant	-0.018*	0.104	0.011	-0.082***	0.290**	-0.002	-0.227***	0.001	-0.021**
	(0.010)	(0.121)	(0.013)	(0.028)	(0.124)	(0.007)	(0.075)	(0.068)	(0.008)
MKT-RF	0.003*	-0.013	0.003	0.025***	-0.012	0.000	-0.004	0.001	0.002
	(0.002)	(0.025)	(0.003)	(0.008)	(0.037)	(0.002)	(0.016)	(0.023)	(0.002)
HML	0.007	0.088***	-0.002	-0.028	0.007	0.007**	0.069**	0.016	0.017***
	(0.005)	(0.033)	(0.005)	(0.018)	(0.039)	(0.003)	(0.035)	(0.048)	(0.004)
SMB	0.003	-0.073	0.000	-0.031***	-0.030	0.003	0.003	0.000	-0.006**
	(0.005)	(0.046)	(0.005)	(0.011)	(0.069)	(0.003)	(0.029)	(0.037)	(0.003)
RMW	-0.007	0.043	-0.010	-0.043	0.047	0.003	0.063	0.017	0.005
	(0.007)	(0.057)	(0.011)	(0.039)	(0.076)	(0.005)	(0.060)	(0.057)	(0.007)
CMA	-0.012**	-0.051	0.002	0.041	0.212**	0.003	0.007	0.023	0.000
	(0.006)	(0.049)	(0.006)	(0.041)	(0.081)	(0.005)	(0.059)	(0.083)	(0.005)
MOM	-0.001	0.032	0.001	0.044**	-0.027	0.002	0.006	-0.010	0.003
	(0.004)	(0.037)	(0.002)	(0.019)	(0.051)	(0.003)	(0.022)	(0.023)	(0.002)
LIQ	-0.001	0.004	-0.002	-0.023	0.067	-0.002	-0.047**	-0.057	-0.006**
	(0.004)	(0.029)	(0.002)	(0.015)	(0.046)	(0.002)	(0.022)	(0.040)	(0.003)
Observations	144	144	60	84	84	84	144	144	144
Adjusted R-squared	0.01	-0.02	-0.06	0.08	0.02	-0.03	-0.01	-0.03	0.13

Table 7: Alpha of Long-Short Strategies Based on GHG Emission Intensity

Lag	CDP: GHG SCOPE 1	CORPORATE DISCLOSURE: CO2 TOTAL
1 month	0.357**	0.303**
	(0.146)	(0.151)
2 month	0.350**	0.303**
	(0.151)	(0.152)
3 month	0.338**	0.286*
	(0.143)	(0.153)
4 month	0.339**	0.268*
	(0.140)	(0.153)
5 month	0.340**	0.289*
	(0.146)	(0.149)
6 month	0.351**	0.276*
	(0.146)	(0.148)

Table 8: Impact of the Paris Agreement on Carbon Premium

	CDP: GHG	CORPORATE DISCLOSURE: GHG	CORPORATE DISCLOSURE: CO2	
	SCOPE 1	SCOPE 1	DIRECT	TOTAL
GHG_EMISSIONS (INTENSITY)	-0.047**	-0.197**	-0.323***	-0.035**
	(0.021)	(0.081)	(0.089)	(0.016)
DUMMY_POSTCOP21	0.020	0.150**	0.189**	0.014
	(0.017)	(0.072)	(0.083)	(0.023)